ROLE OF ANIMAL BREEDING STUDIES IN FARMING SYSTEMS RESEARCH

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I. INTRODUCTION

Animals are important components of farming systems practiced in the tropical areas of developing countries. This can be illustrated by their large number in comparison to the world animal population (Table 1).

In small and medium farms, they fulfill important roles as a source of high quality nutrients (milk, meat), shelter (wool, fibre, skins), draught power, and manure. Additionally, they often constitute a means of savings. In some peasant communities, they even play a social role. Animals also utilize pastures, crop residues, and left overs that otherwise cannot be utilized by the human population.

Animal production and productivity in tropical areas are considerably lower than in temperate areas or developed countries. As a result, availability and consumption of high quality protein are insufficient in most developing nations.

Animal based farming systems practiced by small/medium farmers in the tropics could be classified in general terms as follows:

- Subsistence farms (small; mixed crops-animals).
- Subsistence/commercial (small and medium farms; mixed crops-animals), and,
- Commercial (small and medium; mainly livestock).

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In this classification the key element is the orientation of the production for subsistence or commercial purposes. This will have an influence over the type of technology that could be used for their improvement as farmers' goals, resources and production objectives would be different.

The type of crops and animals present in the different systems will vary according to location. A detailed classification has been provided by McDowell and Hildebrand (1980) and is included in Annex I.

The systems approach has been proposed to study ways of overcoming the technological limitations encountered in small/medium farms. This requires a holistic, multidisciplinary study of the farm, including its resources, management and outputs. Farmer participation, his goals and aspirations are key elements in this approach. With regard to the improvement of the animal components it requires the study of its genetics, feeding, management, health and production economics. The interaction with the other farm components and the exogenous factors (environment, markets, policies) is also considered.

During the past decade an increasing amount of Animal Sciences projects have been supported in the developing world. For instance, IDRC support for Animal Sciences rose from 6 projects (CAD$1,573.500) in 1976 to 23 projects (CAD$11,687.950) in 1987. The majority (93%) have looked at improvements in animal production through the feed component, as it has been widely recognized to be the main constraint in animal production systems.

Animal breeding studies per se have not been supported by the Centre due to the fact that in many situations they are not considered a main priority.

The long-term nature and limited impact of many research/development programmes that included animal breeding have also contributed to this situation. Animal crossbreeding studies within Farming Systems projects has been considered in a limited number of cases. The need to improve the animal genetic base seems more evident as improvements are obtained in the production environment (feeding, health), and the demand for animal products increase within favourable market conditions. This has been demonstrated by several studies conducted throughout the world. However, issues still remain with regard to the conditions under which support for animal breeding studies is merited, the type of studies needed in the tropics, the ways to disseminate improved stock, etc.

The purpose of this document is to review experiences in animal breeding research in the main species in the tropics, draw conclusions and make suitable recommendations.

In particular, a general policy for IDRC support of animal breeding research will be recommended.

In conducting this study, the majority of studies have been drawn from Latin America. This reflects the authors' experiences and the availability of information. However, it is expected that the main conclusions can be generalized to other parts of the tropical world.

2. CATTLE

2.1 Background

Cattle are numerically the most important domestic species in developing countries (Table 1). In some regions, the cattle in the hands of small farmers constitute very important proportions of the national totals. Thus, taking Central America as whole, 15% of the total cattle population is found on farms of less than 7 ha, and 37% of the total on properties smaller than 42 ha (SIECA, cited by Paladines, 1988).

In most farms in the tropics, cattle are of dual or even triple purpose. In Latin America, for example, Seré and Rivas (1987) estimated that dual purpose animals constituted 25 to 94% (unweighted mean: 70%) of the national milked populations in 15 tropical countries, and that milk derived from them accounted for 6 to 75% (mean: 40%) of the total production. The dual purpose systems in Latin America are particularly common on small farms. Thus, the specialized populations of dairy and beef animals tend to be concentrated in the medium and large commercial herds, located principally in the temperate regions (dairy) or lowland tropical areas (beef).

The dual purpose system so prevalent in Latin America is typically based on crossbred cattle of mixed European, zebu and criollo inheritance. Cows are generally milked with calf at foot, sometimes only seasonally. Feeding is based principally on pastures with occasional supplementation with crop residues, but very little purchased feed inputs. On small farms, males may be retained for work or otherwise sold for meat at ages which vary widely between herds. Health care is usually deficient and very few farms keep production records. Despite the low levels of production obtained, there is a wide consensus of opinion that these herds offer the best opportunity for increasing the production of meat and milk at reasonable costs throughout the tropical region, and that their development can make an important contribution to improving the standards of living of the neediest members of the rural populations (Preston, 1976; Seré and Vaccaro, 1985; Seré and Rivas, 1987).

Animal Breeding studies on cattle have accounted for an important proportion of scientific papers published from the tropics, especially in Asia and Latin America. In Latin America, for example, papers in this field were more numerous than those in any other discipline among a sample of 473 articles published on cattle (Table 2). It is, however, argued that the contribution of the work done has fallen far short of the real needs for information applicable to rural development and the purpose of the following section is to point out the potential application and limitations of available knowledge. The discussion will be based mainly on dual purpose cattle for the previously mentioned reasons.

2.2 Developing more productive genetic groups to respond to environmental improvements in the production system

A fundamentally important area of Animal Breeding studies is that concerned with the determination of the most productive genetic groups for given production systems. Unfortunately, reliable information is extremely scarce for two main reasons. First, the majority of research has been concerned with one or two production traits, instead of attempting to describe total productive performance by including together data on fertility, survival and production. For example, as many as 61% of the Animal Breeding studies referred to in Table 2 dealt with only one production trait, and an additional 17% dealt with only two. Thus, the results give a partial vision of productive performance in each case, which is inadequate for development planning. Secondly, despite the large number of publications describing the comparative performance of different genetic groups, extrapolation of the results to other conditions is usually difficult because insufficient information is given about the environmental conditions under which the results were obtained. Both these problems are directly attributable to the incorrect application in tropical conditions of methodologies used in temperate zones where variation in productive characteristics between available genetic groups is much more limited and differences between production systems within large geographical areas are relatively small.

Despite these difficulties, it seems probable that pure European breed cattle offer the best potential for production in the temperate regions of tropical countries where, in any case, they are usually predominant. Some advantage may be found for European x criollo crossbreds in fertility (Silva y Verde, 1983b) and possibly in survival rates, which appear not to have been documented, but the difference in fertility seems likely to be offset by the much higher milk yields per lactation of the European purebreds (Silva et al., 1981; Silva y Verde, 1983a). Table 3 shows aspects of the performance of pure Holstein Friesian cattle in a large number of commercial herds in intensive, specialized dairy production systems based on grazing (Colombia) and complete confinement (Mexico). The farms were located at between 500 and 2600 m above sea level, mainly above the zone of climatic stress. The levels of performance in all traits are very satisfactory by tropical standards. However, the average lactation milk yields fall short of those expected in the countries of origin (USA and Canada) of the cows by about 1000 kg in each system. Furthermore, the coefficients of variation (over 40%) are unusually high by the standards of temperate countries (20-25%). The mean calving intervals exceed those of temperate countries by 20-30 days and the age at first calving in Colombia is about 6 months longer than normal. Taken together, this evidence suggests that environmental, rather than genetic, factors are the main limitations to be productivity of the tropical systems. This seemed to be especially true on the smaller Colombian farms, since milk yields in herds with less than 50 records were only

3096 kg, on average, compared with 4368 kg in herds with over 100 records.

The exact reasons are difficult to identify. Probably the main cause is the difference in the quality of the diet since concentrate feed costs in tropical countries are usually so high relative to milk prices that their use must be restricted, and pasture quality may also be inferior due to management factors. Pasture or forage quantity is frequently limited because of the very high opportunity cost of the temperate lands commonly used for these kinds of production system and which results in overstocking. General management standards are also likely to explain part of the difference. Great difficulty is experienced in maintaining the constant supply of goods and services (e.g. veterinarians, machinery repairs, medicines) which are essential to the efficient running of high-yielding dairy herds, and the low proportion of owner-operated large herds in Latin American countries inevitably affects the degree of dedication of the people involved. There is, however, no evidence that genetic groups other than pure European cattle would be more productive for production systems in the temperate areas and it appears that their genetic potential for yield has yet to be challenged.

Genetic causes may, however, be a limiting factor to the production from European cattle at very high altitudes. At Huancayo, Peru (3300 m), family units were established with European cows grazing irrigated ryegrass-clover mixtures at a stocking rate of 3-4 cows/hectare and no supplementary feed (Bojórquez et al., 1976). Very satisfactory mean milk yields (3155 kg/lactation) and calving intervals (13.9 months) were obtained, but 52% of the cattle brought up from the coast died or were culled within two years of arrival and 45% of the calves born locally died before reaching twelve months of age, due principally to high altitude sickness. It was concluded that the scheme should be based on European x local criollo stock, in the hope that survival rates would improve.

In the hot, lowland tropics, the situation is far less clear. The existing animals in traditional systems (usually zebu and zebu crosses) are relatively unproductive once environmental improvements are introduced into the production systems. However, total productivity starts to decline beyond a certain grade of European breed inheritance because of the serious reproductive and survival problems which cattle of a high genetic potential for milk yield present under hot, tropical conditions. In general, crossbred cattle (Bos taurus x Bos indicus) of intermediate levels of European inheritance are most productive under a wide range of conditions in the tropical lowlands. This is shown in Figures 1 and 2 with examples taken from cattle of various grades of European breeding in different countries. An attempt to quantify total productivity, instead of single traits, was made by combining milk yield and fertility in Figure 1 (kg milk per day of calving interval) and fertility with survival in Figure 2 (number of heifer replacements surviving to first calving age, produced in the lifetime of the dam). The results are supported by a great deal of published information and by the official opinion of bodies such as FAO (1979).

It is, however, clear from Figures 1 and 2 that the most productive grade of cross varies from one environment to another. Thus, in Bolivia where yields were low and the environment very poor, cattle of 50% were superior (Figure 1) while in Cuba where environmental conditions are excellent and yields much higher, the 50% European crosses produced more than the other groups. That these interactions may occur between farms within fairly limited geographical regions is shown by the data from commercial herds in southeast Brazil in Figure 3. Here, purebred European cows produced more milk on "better farms" where yields were higher, while lower grades were more productive where mean yields were lower on the "poorer" farms.

Unfortunately, the recent literature contains too many examples where genetic groups have been wrongly matched to environmental conditions and the resulting productive performance has been unsatisfactory. In some cases, this results from the spontaneous action of farmers, as shown in Table 4 which gives data from the European cattle brought down to the lowlands by colonists in Santa Cruz, Bolivia. Milk was produced under very poor conditions mainly from volunteer grass species growing after rice had been sown on cleared forest land. Under such conditions, the high genetic potential for milk production of the European cows was not expressed and their fertility was so poor that they produced less total milk (per cow in the herd/year) than any of the other breed groups. Very similar results were obtained from medium sized herds in Barinas State, Venezuela, where feeding and management standards were also generally low (Table 5).

In other cases, however, the negative results follow from officially backed policies aimed at increasing production. One such example is described by Wilkins et al. (1979) again from the Santa Cruz region in Bolivia where European breeds were imported under a bilateral cooperation agreement. They were unprofitable whether stabled or on pasture, where they produced less milk per year than local crossbred cows (Table 6). It is most important to point out, as did Wilkins et al. (1979), that such ill-planned schemes not only fail to increase production levels but also reduce profitability because costs rise, due mainly to higher purchase prices and costs of feed and veterinary care. Another example is shown in Table 7 and refers to purebred European cattle imported in the last few years into Venezuela with dollars authorized by the government at preferential prices. Herd average milk yields were generally high for the lowland tropics (over 4000 kg/lactation), but the rates of loss from abortion, still births and postnatal death or culling were so high that the herds were unable to maintain their numbers. The farms in question were large commercial or institutional ones with high levels of management by tropical standards, so that the results might have been even worse had data been available from small farms. A particularly disturbing aspect of this example is that the diet of the cattle was based very heavily on concentrate feeds, about 70% of which were imported. Per capita consumption of milk fell drastically in the same period because of the rise in price and the heavy foreign debt was further increased by the purchase of the animals, their feed and medicines.

In complete contrast to the foregoing cases, Table 8 shows one of the best documented examples of how correctly planned genetic improvement programmes can contribute to rural development. The data refer to the Indo-Swiss development project in Kerala, India. The integrated programme involved farmer training, a strong pasture improvement plan with seed evaluation and distribution, animal health care, performance recording, artificial insemination with progeny tested crossbred bulls (Brown Swiss x zebu) and cooperative marketing organization (Kerala Livestock Board, 1985). As shown in the Table, the local zebu cattle were incapable of responding to the improvements in feeding and management, since their yields were the same whether they received concentrate supplements on pasture or not. However, the crossbred cows produced over twice as much milk as the native cattle on pasture and over three times more with supplementary feed. The success of the project in terms of farm income is shown by the 200-300% increase in net income which was generated by the crossbred cattle, as compared with the original stock (Table 8). Furthermore, the dairying enterprise competed favourably with crop production and permitted diversification of the production system as well as contributing to the control of soil erosion. Some additional examples of successful genetic improvement programmes are summarized in Table 9. In all cases, the base for comparison is the existing local breed, usually zebu, and the improved animal a European cross. The increase in milk yield varied from 43 to 352% over the native base. In some cases, fertility and mortality were also improved and in no case reduced by such an extent as to cancel the increase in milk production. For example, despite the higher mortality of the predominantly European crossbred calves in the Panama farm, the net income derived from these animals was 21% higher per animal unit. The results from Cuba and the two Indian sources are of particular interest because they refer to the improvement obtained in one single generation from a crossbreeding programme, where native cattle have been crossed with European breeds. Thus, similar results are to be expected in a relatively short period of time provided the product can be profitably marketed and provided that farmers are supplied with the necessary technical information and inputs to make the environmental changes which the more productive animal require to express their higher potential.

Taken together, this evidence shows the importance of matching the genetic potential of cattle correctly to prevailing environmental conditions and the very great impact on farm output and income which results if this is achieved. To avoid further planning mistakes, it is essential to define objectively the environmental components of the system which are required for animals of a specific production potential to perform satisfactorily. It will have been noted that in this paper it has only been possible to define conditions in subjective terms, usually taking the level of milk yield obtained as indicative of the level of environmental improvement. But methods should be developed of using objective descriptors, which might include levels of feed availability throughout the year, disease control measures, key management practices and selected climatic data, so that the productive performance of new genotypes might be more successfully predicted in lowland development projects.

It is also essential to promote agreement between research workers as to the production traits which should be described in order to define productivity of cattle under tropical conditions as accurately as possible. Resources continue to be wasted because of the incomplete results which are published, making the extrapolation of the data to other situations impossible. Guidelines should be established giving the minimum indispensable information required for this purpose, which would appear to include milk production, fertility and survival in specialized dairy systems and growth rate in addition in dual purpose ones. Then efforts should be made to encourage the adoption of this methodology as widely as possible among professionals involved in the evaluation of the performance of cattle, whether in genetic research studies or in development projects.

2.3 DETERMINATION OF THE EFFECTS OF ENVIRONMENTAL FACTORS ON PRODUCTION LEVELS

A second area of Animal Breeding studies which deserves consideration is that concerned with the quantification of the environmental effects which influence production levels. One purpose of these studies is to enable production records to be adjusted so that they reflect the genetic values of the animals as closely as possible, and thus permit more accurate selection. In addition, they provide indispensable information on how management practices may be altered to maximise production levels.

Taking milk yield as an example, it is commonly found that 70-90% of all variation is due to environmental factors such as herd, year, season, age of cow, milking system (with or without the calf), number of milkings/day, lactation length, previous dry period length and the length of the actual calving interval. Examples of the magnitude of some of these effects are shown in Table 10. It is recognized that in most cases the data were not treated statistically in such a way as to permit precise estimates of the effects in question (e.g. by least squares analysis), but they are nevertheless considered to offer a realistic idea of the general situation.

The data on herd effects reflect the fact that this is usually the principal source of variation in production traits in cattle populations, even within small geographical regions. They are of considerable practical interest because they can help identify good and bad management practices and thus contribute to the transfer of useful technologies. The variation shown in Table 10 due to years illustrates the typical fluctuations which are to be expected, particularly in grazing systems, due to droughts, floods, disease outbreaks and, occasionally to political and economic changes. Changes of this magnitude can seriously complicate the interpretation of the real impact of development programmes.

Seasonal effects are difficult to predict and may be very important.

Possibly the most common situation in the lowland tropics is where yields are higher during the rainy season due to the improved quantity and quality of the fodder available, as shown in Table 10 for the Colombian and Venezuelan herds. However, excess moisture may be detrimental because of the low dry matter content of the forage actually ingested. Also, the animals may have difficulty moving about in search of food and water and may be greatly bothered by flies. Under such conditions, wet season yields may be similar to, or poorer than, those obtained in the drier months of the year, as shown in the data from Puerto Rico. Important seasonal trends may also occur for quite different reasons. Such was the case in the Bolivian herds where yields fell drastically in the month when rice was harvested, because available labour was diverted from the animals to the crop component of the production system.

The effect of the age of the cow on yield is also highly variable, and it is impossible to predict because of differences due to breed, selection practices and age at first calving. In any case, as shown in Table 10, this factor may explain differences in milk yield which are quite as important as those due to herd or to year.

Finally, Table 10 gives information on the variation in milk yield due to the system of milking. As shown by the Mexican data, an increase in the amount of saleable milk, as well as in total milk yield, may be expected if calves are raised by restricted suckling after milking, instead of being weaned and reared artificially. This has been demonstrated with animals of mixed zebu, criollo and European inheritance which constitute the majority populations on small farms in the lowland tropics. In some populations, the presence of the calf appears necessaryn to stimulate milk "let down". This explains the higher yields obtained when the Colombian criollos were milked with their calves at foot. However, recent evidence (Fernández Baca et al., 1986) suggests that this sensitivity may be overcome to a large extent by tactful management of heifers before and after calving for the first time, so variable effects of milking system must be expected between farms as well as between genetic groups.

The environmental factors considered in the foregoing cases are likely to explain most of the non-genetic variation in milk yield, though the list is by no means exhaustive. The same factors generally have equally important effects on the other productive traits such as fertility, survival and growth. Examples are shown in Table 11 which are typical of those observed under lowland tropical conditions. It may be noted that the most favourable conditions for high levels of performance in one trait may not be best for others. For example, calving in the rainy season may maximize milk production but may well lead to higher calf death rates. Similarly, milking with restricted suckling may increase milk yields and calf growth, but may also reduce annual calving rates. It is thus clear that careful local studies of the environmental factors affecting total production are an indispensable part of development programmes, not only from the genetic point of view which will be discussed in further detail below, but because they provide basic information for proper management strategies and for the correct interpretation of trends which occur in production levels.

2.4 DETERMINATION OF GENETIC PARAMETERS OF PRODUCTION TRAITS

A third category of study considered in this paper refers to the genetic parameters of production traits, including heritabilities, genetic correlations and genotype: environment interactions. In all these areas, information is either completely lacking or of very limited utility, especially as applied to the cattle populations of the lowland tropics.

The majority of estimates of genetic parameters from tropical cattle have very large errors, due to insufficient numbers of observations. The more reliable estimates apply to the specialized dairy and beef populations, because it is from these that most production data are recorded. The bias in Animal Breeding Research towards these populations, despite the fact that the non-descript dual-purpose populations constitute the majority in most tropical countries, is shown in Table 2 from which it may be seen that only 12% of the published papers referred to dual purpose cattle. There is thus practically no reliable information on the genetic parameters of these cattle. Part of the reason lies in the shortage of production records from these herds. For example, in a survey of dual-purpose herds in tropical Latin America, Seré and Vaccaro (1985) found that only 2 - 33% farms kept production records. Of these, far fewer would be expected to have sire identification of the cows which is necessary for computing genetic parameters by the usual method.

Another difficulty refers to the computational methods which are used. A common example concerns the estimation of the heritability of milk yield. In temperate countries, the records of cows with short lactations, and therefore low yields, are routinely omitted from the calculations because it is assumed that such records are abnormal. In any case, they rarely account for more than 5% of the total. In tropical conditions, the same procedure is also commonly applied, ignoring the fact that short lactations may constitute 20-50% of all records and that they may be due to genetic causes. Thus, by leaving them out, the importance of genetic variation in milk yield is likely to be underestimated. This probably explains why heritability estimates of 15%, instead of the 20-30% common in temperate zones, have so often been found in tropical populations (Camoens et al., 1976; McDowell et al., 1976; Valle, 1981; Abubakar et al., 1986). If these very low values are confirmed when all records are included in the calculations, then response to selection for milk yield will be extremely slow and the accurate selection of breeding stock even more costly and difficult than it is in temperate countries.

But it is obviously essential to establish appropriate methodologies and apply them uniformly in future studies, with special emphasis on the majority populations of the tropical lowlands.

A second example concerns reproductive efficiency. This trait is perhaps the most important of all, due to its fundamental economic value in all production systems. It is traditionally considered to be of near zero heritability and is therefore usually not included in genetic improvement programmes in temperate countries. However, the parameters usually employed to measure fertility, such as services per conception or intervals between calvings, do not take into account the performance of "problem" cows which fail to conceive or calve again. Under tropical conditions, the proportion of "problem" cows may be very high, especially in intensive systems where reproductive causes may account for over 50% of the total losses from the herd (Vaccaro et al., 1983). Consequently, omission of information from such animals is likely to reduce the genetic variation in fertility which can be quantified. The appropriate methodology to take the real variation into account has yet to be developed, but evidence that the true heritability of reproductive traits is higher in tropical than in temperate conditions is given by the values of approximately .30 available from zebu breeds in beef herds (Plasse and Verde, 1988). If this were true in dairy and dual purpose populations, as seems probable, then reproductive efficiency should be given priority in genetic selection programmes because of its very great economic importance.

Urgently needed as well is clearer information about the genetic correlations between production traits. One issue of particular importance concerns the possible negative correlation between milk yield and fertility in cows. Under temperate zone conditions, a tendency is occasionally observed for high yielding cows to be less fertile and there is some evidence that this is due to genetic causes (Kragelund et al., 1979; Hansen et al., 1983). In the tropics, however, the tendency is usually very marked as shown by the results in Table 12 derived from commercial dual purpose herds in the State of Zulia, Venezuela. It may be seen that as milk yield rose from 1000 to 3000 kg per lactation, the interval from calving to conception more than doubled and the proportion of anoestrous cows in the herd increased from 17 to 65%. Thus, if reproductive efficiency is more heritable than previously thought and if the relationship between yield and fertility is due to genetic causes, then existing genetic programmes which emphasise milk yield may lead to an increase in milk production per lactation at the expense of reproductive efficiency and therefore nullify overall progress.

Another genetic relationship which may be important is that between milk yield, expressed as saleable milk, and calf weights at weaning in dual purpose populations. Presently, tropical dual purpose herds are very seldom selected for calf growth and whatever selection is applied is usually in favour of saleable milk. Recent results from Costa Rica (Aragon and Deaton, 1981) and Venezuela (Vaccaro el al., 1986a) suggest that cows which produce most during milking tend to have calves with lower weaning weights. The magnitude of this effect is shown in Table 13 where the records for calf weight of the five highest yielding cows in a commercial herd in Venezuela are tabulated. If this negative relationship is shown to have a genetic basis, then selection for saleable milk will tend to reduce calf weaning weights at weaning. It is therefore necessary to quantify the relationship between milk yield and weights at weaning, as well as subsequent ages, particularly in populations where the value of meat is relatively high.

The issue of genotype: environment interactions is of particular significance in the context of the importation of animals and semen from temperate countries, which takes place constantly even in the poorest tropical countries and is frequently promoted by powerful commercial interests. Since very few tropical countries have their own bull progeny testing schemes, the importation of proven bulls, or semen, would provide an attractive alternative, provided that the "best" bulls for use under tropical conditions could be identified. There appears to be absolutely no justification from the genetic point of view for the importation of live breeding stock, whether males of females, into the tropics from temperate zones. Great importance is, however, attached to the strategic use of semen. There is considerable evidence to show that sires which have been proven positive for milk yield in temperate countries will produce superior purebred progeny for use in intensive systems in the tropics (McDowell et al., 1976; Powell and Dickinson, 1977; Menéndez and Guerra, 1981; Abubakar, 1985). Thus, the importation of semen from superior progeny tested sires could be recommended, particularly to breed young bulls locally for use in intensive systems. However, in the semi-intensive and dual purpose systems such as predominate in the lowland tropics, where temperate zone proven bulls could be used to produce crossbred progeny, there is unreliable and contradictory evidence as to the genetic quality of the most suitable sires (Moulick, 1978; Parekh and Sahu, 1978; Parekh and Pande, 1982; Buvanendran and Petersen, 1982). It is particularly important to generate information on the genetic characteristics of the European x breed bulls to use in these systems because the populations represented are precisely those which will have greatest difficulties organizing their own bull selection programmes (See Section 2.5).

The examples cited in this section illustrate the extremely unsatisfactory state of knowledge in this area of Animal Breeding. The main limiting factor at present is the scarcity of production records, especially among the lowland populations. Farmer education may be a serious obstacle as, for example, in the dual purpose herds in Barinas, Venezuela, where 63% of the owners were effectively illiterate (Table 5). However, efforts must continue to implement simple recording systems which provide information on the principal production traits. Far more work is needed in this area. Many existing recording systems are unnecesarily complicated, including information which is of no interpretative value and excluding other data which are required. There is also insufficient information on the optimum frequency for recording production data. For instance, it is suspected that the conventional system of monthly sampling of milk yields leads to unacceptably large errors in predicting total yields under tropical pasture-based systems (Lindstrom, 1976), but increasing the frequency increases the costs of the service and accurate information is therefore required on the relative precisions and costs of recording at different intervals of time. Methods also need to be developed for estimating the fertility of "problem" cows and for predicting weights in mixed, commercial populations from body measurements, because so few farms have balances suitable for weighing cattle. From the genetic point of view, more records are urgently required for estimating heritabilities and genetic correlations, especially in the lowland populations for which so little information is currently available. These parameters will determine whether selection programmes represent a justifiable use of scarce resources and, if so, how best they should be designed and implemented. It must, however, be emphasized that research into the methodology of production recording in tropical herds and the promotion of recording schemes is not only essential for genetic purposes, since accurate records constitute a fundamental element of any improvement programme because intelligent decisions about herd management and feeding cannot be made without them.

2.5 MATING SYSTEMS AND THE SELECTION OF BREEDING STOCK

It was suggested in Section 2.2 that cattle of pure European breeds are likely to be most productive in dairy and dual purpose systems in the temperate areas of tropical countries. The pure mating systems involved presents no special problems and the genetic programme must therefore place emphasis on making correctly selected breeding stock available to the farmer.

Data published recently from Mexico and Colombia show a considerable advantage in milk yield from using semen from bulls proven superior for milk by progeny testing in the USA and Canada, with very little adverse effect on their fertility or herd life (Table 14). These results confirm trends reviewed previously in Section 2.4 for intensive production systems. It is therefore of particular concern that productive traits are frequently not the main criterion in the selection of breeding stock. For example, data from three Latin American countries show that less than half the bulls from which semen was imported from abroad were superior for milk yield, which is the trait of principal economic interest in intensive systems (Table 15). In contrast, equal or more importance was given to external appearance ("type") which bears no genetic relationship to productive characters. Under temperate conditions, Van Vleck (1977) showed that excessive attention to external appearance was one of the chief factors which explained why genetic progress for production fell short of the rate which was theoretically possible. This may be tolerable in countries where over-production is a problem but is completely unacceptable in tropical countries where more, cheaper food is so urgently needed. Not only is genetic progress for production hampered by the application of incorrect selection criteria but production costs are also directly increased because of the high prices paid for semen from high "type" and "fashinable" bulls (Madalena et al., 1985).

Although the small farmer is not usually involved in the importation of animals or semen, he does rely on these herds as sources of young bulls and is thus forced to cover the costs of the inefficient selection procedures. It is essential to protect his interests as well as those of consumers in general. This must be done principally by educational campaigns at all levels and by the official enforcement of guidelines regarding the genetic quality of local and imported breeding stock and semen. Suggestions as to the standards which might be adopted have been set out in a document to be published by the Latin American Association for Animal Production. It is believed that a real impact could be made on the genetic improvement of cattle for use in intensive, temperate systems simply by the reorganization of existing resources. Since these herds are frequently also the source of bulls used in semi-intensive systems for crossbreeding, the positive effect should filter down through the rest of the national herd.

In the lowland tropics, the problems are considerably more complicated, both with regard to the most suitable mating system and with regard to selection criteria. As was shown in Section 2.2, crossbred animals with Bos taurus and Bos indicus inheritance are likely to prove most productive in the majority of herds. Probably the most important practical genetic problem confronting these herds is the choice of an appropriate mating system. The system must maintain the herd at the required intermediate level of European-zebu inheritance, must permit reasonable genetic progress and must be eminently practical and easy to apply. The two alternatives are the use of rotational crossbreeding, where the sire breed is changed every generation, or the use of crossbred bulls. The theoretical advantages and disadvantages of both systems have been discussed elsewhere and the conclusion reached that the most suitable system is likely to be that based on crossbred bulls, bred from outstanding local dams and imported semen (Vaccaro, 1987a). However, no comparative data are available and priority should be given to demonstrating the comparative merits of the systems under commercial conditions. The use of crossbred bulls is likely to be particularly suitable for small farms, because it avoids the need for simultaneous access to bulls of more than one breed and eliminates the fluctuation in production levels which occur when European and zebu sires are used in rotational crossing. The need for comparative data is particularly urgent because certain popular prejudice exists against the use of crossbred animals as sires, and this explains to a large extent the numerous cases in which continued use has been made of European bulls, leading to excessive levels of Bos taurus genes in the herds and the consequent reduction in overall productivity. The information required should include the means and variation in the principal productive traits and should take into account the fact that one of the advantages of the crossbred bull system is that it permits the use of natural service, whereas the rotational system require either the use of AI or the purchase of expensive European breed sires.

A second aspect of the mating system concerns the European and zebu breeds which should be used in the crossbred populations in the lowlands. There appears to be no justification for changing the zebu base breed from that which is locally available. However, a choice may be made between the European breeds available for crossing. Among the main dairy breeds, Holsteins have been found consistently superior to Brown Swiss for use in crossbreeding programmes with zebu or criollo cattle (Table 16). Holsteins have also produced more than Jerseys in terms of output from the crosses (Syrstad, 1985), but the smaller body size of the Jersey crosses could prove an advantage in terms of efficiency of production where feed supplies are limited. However, in most Latin American markets this possible advantage would probably be offset by their inferior carcass quality. There is no reliable information on the merits of the classical dual purpose European breeds (Simmental, Normandy) as compared with the specialized dairy breeds (Holstein Friesian) for use in crossbreeding and this would be of interest because the former might have an important contribution to make in lowland dual purpose systems, especially where the emphasis is on meat rather than milk production.

Once an appropriate mating system has been established, attention must be turned to selection. The data shown in Table 17 illustrate the extremely wide scope which exists for selection to improve performance in ordinary, lowland commercial herds. The data are expressed as deviations from contemporary means in an effort to reduce variation due to environmental factors and establish the true productive potential of each cow more accurately. Thus, in herd 1, the best cow for milk yield produced 3058 kg more and the worst cow 1694 kg less milk than the average of their contemporaries, which is an impressive range since the overall mean was 2896 kg. The data from herd 2 are of special interest because they were zebu cows with a mean yield of 1584 kg milk. Similarly large differences were observed between the cows with regard to the weaning weight of their calves. Although the genetic impact of selection in these herds cannot be predicted accurately because of lack of information on the genetic parameters (see section 2.4), an immediate increase in production could clearly be obtained by identifying and culling the least productive individual cows. A rough estimate based on actual data from these herds suggests that yields would be increased 100-200 kg/lactation if the worst 10% cows were culled, and by 300-570 kg/lactation if as many as 40% could be discarded. Through such high culling rates do not seem very realistic, overstocking is such a common problem in tropical herds that the result might be doubly advantageous.

One of the main obstacles to accurate selection of females is not simply the lack of production records, but also, even where they do exist, the fact that the information given to the farmer usually consists simply of the absolute yields of each animal. As was shown in Section 2.3, the environmental factors affecting productive performance are so important that the absolute yields may give a completely misleading indication of the animals' true productive ability. It is thus necessary to express the records as deviations from contemporary means and make other adjustments to take environmental factors into account. With electronic processing, very little extra effort is required to do this automatically and, in this way, the farmer could be provided with a list of cattle in his herd ordered according to their estimated genetic values for productive traits which would serve as a scientific basis for selection. Computer programmes to do this need to be designed specially for tropical conditions because the production traits, and the environmental factors affecting them, are different from those considered under the conditions of temperate countries.

Another difficulty concerns the methods available for the simultaneous selection of cows for various traits. In dual purpose herds, these should probably include fertility, milk yield and growth rates, while fertility and milk yield at least should be included for populations kept under specialized, intensive conditions. The most efficient selection method for multiple traits is the selection index but this can rarely be used under tropical conditions because it requires knowledge of the genetic parameters of the traits in question. It also requires information on the relative economic value of the traits, which is difficult to find and notoriously unstable under most tropical conditions. Thus new, simpler methods must be evolved and their effectiveness demonstrated in commercial herds.

The selection of bulls also presents special problems in most tropical environments. Sire progeny testing for traits such as milk yield may be less accurate than in temperate countries because of the apparently lower heritability. Furthermore, it may not lead to maximum genetic progress in the population per year unless specific conditions are met. These conditions include populations of cows in artificial breeding and milk recording numbering about 6000, or more, with good fertility and survival rates, low ages at first calving in the daughters and low ages at production of freezeable semen in the bulls themselves. There are relatively few regions in the tropics where these requirements are fulfilled, or seem likely to be fulfilled in the forseeable future. In the document on breeding stock evaluation to be published by the Latin American Association for Animal Production it is suggested that progeny testing is not a realistic ideal for the majority of tropical countries and that sire selection based on information from the animals' sires and dams in the best alternative, in genetic as well as economic terms. This emphasizes the urgency of defining and applying proper selection criteria to cows, so that outstanding animals can be used as bull dams. It also points out the enormous benefit which could be obtained if advantage could be taken of semen from sires proven abroad, to produce young bulls. As was indicated in Section 2.4, the necessary information has yet to be generated for crossbred animals used in lowland tropical herds with semi-intensive or dual purpose production systems and, in view of the large numbers of cattle which might potentially benefit, priority should be given to obtaining the necessary data.

2.6 DISTRIBUTION OF GENETICALLY IMPROVED LIVESTOCK TO FARMERS

In the final section of this paper, consideration is given to methods of distributing genetically improved animals to farmers.

Artificial insemination has made an extraordinary impact on the genetic improvement of livestock in temperate countries, especially in the case of dairy cattle. Foote (1981) estimated that the genetic value of AI in milk yield in the USA was equivalent to $70 million each year. The impact in tropical countries might be expected to be even greater because of the very much lower genetic potential of the majority of the existing populations. But the real possibilities must be considered in very careful perspective.

In most tropical cattle populations, low fertility is the norm, with calving rates of 40-50% commonly reported from the lowlands, and 50-70%

for the temperate zones (FAO, 1977). This, more than any other single factor, explains the low levels of production of milk and meat. The measures required to improve fertility include improvements in feeding, management and health, but they are often a question of reorganising existing resources in a rational form, rather than of heavy financial investment. In Venezuela, for example, research data exist to show how calving rates have been raised from 40-50% to 60-70% by improved management and selection over a period of 6 to 7 years (Chicco et al., 1977). If these could be implemented on a national scale to increase the current calving rate from 45% to 65%, a not unrealistic goal, the present deficits of meat and milk would be eliminated. Thus, integrated programmes to improve cattle fertility should be priority in this, and other tropical countries with similar problems. Against this background, the routine use of AI cannot be justified if it leads to reduction in calving rates, which is often the case. For example, Paterson et al. (1983) found a reduction of 6 percentage points in the calving rates of dual purpose and beef cattle on a South African research station when AI with follow-up natural service was used instead of natural service alone, and a fall of as much as 22% when AI only was employed. The difference was more marked in the case of Bos indicus crossbreds than in European breed cows. In tropical dual purpose cattle of mixed European zebu breeding in Zulia, Venezuela, AI was associated with a loss of 12 percentage points in conceptions to first service, compared with natural service (Table 11). The effects on calving rate were not given in this case, but they are believed to be commonly in the order of 5 - 15%. On small farms, the difference might be even greater because they would generally have to rely on an AI service, whereas the Zulia farmers usually have their own equipment and inseminators.

As Bane and Hultnas (1974) pointed out, a very considerable degree of skill and organization is required to establish AI services satisfactorily under tropical conditions and no service should be designed without technically supervised, expert planning and implementation. The human resources to do this properly are among the scarcest available, especially in the lowlands. Farmer education, with special emphasis on correct heat detection is essential and appropriate means of overcoming the usual difficulties of communications and of guaranteeing prompt supplies of semen and nitrogen must be found. Countless programmes in the lowland tropics have also failed because they have not had semen from the right kind of bulls available. The continued use of European breed bulls has rapidly produced 3/4 Bos taurus herds, quite unsuited to local environments.

If the 12% reduction in conception rates to first service in Zulia reflected differences of the same magnitude in calving rate, which is believed to be very likely, the cows bred by AI would have had to produce 20% more milk per lactation to compensate the 12% fewer cows in milk each year, without taking into account the loss in value of the progeny produced. Under such circumstances, AI must be regarded as a tool for strategic use in achieving specific genetic objectives, rather than as a routine means of obtaining pregnancies. Worthwhile objectives will probably include certain crossbreeding schemes, such as the production of the initial European crossbred population from zebu dams, or the use of imported semen from superior proven sires for the local production of young bulls. Beyond this, the routine use of AI must be carefully justified in genetic terms, unless it can be demonstrated that it does not lead to much difference in pregnancy rates compared with natural service.

Embryo transfer is among the reproductive technologies receiving most attention from research workers and commercial organizations in tropical countries. From the genetic point of view it seems very difficult to justify the use of resources in this field in the developing world. In the first place, genetically superior females cannot be identified with sufficient precision, in the case of dairy cattle at least, to justify their use as donors. Under tropical conditions, cows rarely have more information available on which to base selection than three or four of their own lactation records. If the heritability of milk yield is as low as 15%, as some authors indicate (Section 2.4), then with four records the precision of the estimate of the cow's genetic value would reach only 56%*.

With such a wide margin of error, the cost of approximately $2000 per live calf from such a donor seems impossible to justify. For the same investment, 200 doses of semen from superior sires proven with a 99% degree of accuracy could be purchased, and at least 120 live calves produced. Furthermore, when such an important impact is to be expected from improving calving percentages in ordinary herds, the dedication of highly skilled personnel and large sums of money to embryo transfer cannot be considered to represent the best use of resources. It seems relevant to add in this context, that Van Vleck (1981) estimated that costs in the USA would have to fall to $50-90 per conception (compared with $300-2000 at present) for the technology to be economically competitive in genetic terms. It is also significant that, to date, progeny produced by this method in the USA dairy population have been genetically inferior to those produced normally (Everett, 1986), in terms of their milk production. This is due to a large extent to the application of incorrect selection criteria in the choice of donor cows, and to the lack of precision in the estimation of their genetic values. Both these problems are likely to be more accentuated in the tropics. Perhaps due to ignorance of the genetic considerations and the irresistible attraction of "fashions" in livestock breeding, embryo transfers will certainly continue to be made in developing countries, especially in the "elite" commercial herds of rich

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*Precision = $\frac{n\,h}{1+(n-1)r}$ where: n = number of records (4), h = heritability (.15), and r = repeatability (assumed .30) farmers. Thus, the organizations responsible for the welfare of small producers must be prepared to offer assistance to them in the choice of breeding stock, and help them to avoid paying the exorbitant prices charged for embryo transfer progeny.

Perhaps the most promising method of ensuring the distribution of improved stock at reasonable prices is through the organization of scientifically based nucleus herds, the principal function of which is to produce bulls of reliable genetic quality. These could make a considerable contribution to farms which are unable to operate satisfactorily with AI, including the majority of the small farmers in the lowlands and many in the temperate zones. Nucleus herds have a long history of use throughout the tropics but, at least in Latin America, have generally failed to meet their objectives. This is probably because they have almost always been run by government or other institutions and suffered from the notorious instability of policy, budgets and personnel which characterize them. A viable alternative would seem to be the organization of such herds by farmer cooperatives, or as the results of private initiative, but under strict technical supervision so that the stock produced meet reasonable genetic criteria. It is believed that an important contribution could be made to development projects by encouraging farmer participation in projects of this kind, and it is proposed that models should be set up to demonstrate the advantages and disadvantages of such schemes.

2.7 CONCLUSIONS

a. Methodology for quantifying productive performance.

i. It is necessary to define how productive performance of cattle, especially those in dual purpose systems, should be quantified under tropical conditions. Efforts must be made to promote the adoption of a complete, uniform methodology as widely as possible among professionals involved in the evaluation of cattle, whether in genetics research or in development projects.

ii. The scarcity of production records, especially in the lowland tropics, is a grave obstacle to genetic progress and to all livestock development programmes. As farmer education is often a limiting factor, the simplest possible schemes should be designed and promoted. More research is required to determine the optimum methods of measuring certain traits, such as milk yield and growth rates, under tropical conditions.

b. The role of more productive genetic groups in different systems.

i. In the temperate regions of tropical countries, the European breeds which are usually available, offer the best option for use in prevailing production systems. Genetic improvement constitutes a relatively minor problem. An exception to this may be the systems located at altitudes over 3000 meters.

ii. In the lowland tropics, improvements of up to 300% in levels of performance and net income have been obtained on small farms by substituting improved cattle for existing local stock. However, the most productive genotype varies according to the degree of environmental improvement which can be introduced into the system.

Examples continue to be published where programmes have failed due to the incorrect matching of "improved" genetic groups to farm situations, sometimes with official government backing. To avoid further mistakes and ensure that genetics makes its potential contribution to rural development, research is needed to identify descriptors which will serve as an objective basis for predicting which genetic group will be most suited to given conditions.

c. Importance of environmental factors affecting production

i. Environmental (i.e. non-genetic) factors explain from about 50 to over 90% of the variation in all performance traits under tropical conditions. The magnitude of their effect cannot be predicted *a priori*. Local studies are essential so that production records can be correctly adjusted for genetic selection purposes. They are also indispensable for designing correct management procedures and for estimating time trends which would be indicative of the progress obtained in development projects.

d. Genetic parameters of production traits

i. Knowledge of the genetic parameters of production traits in tropical cattle is totally inadequate, especially in the case of the dual purpose populations predominant in the lowlands. The information is required to determine whether genetic selection programmes represent a justifiable use of scarce resources and, if so, how best they should be designed and implemented.

e. Mating systems

i. The pure mating system required for the European cattle in the temperate regions presents no special problems.

ii. The choice of an appropriate mating system constitutes one of the main problems in the crossbred herds which predominate in the tropical lowlands, especially for the small farmer. Field information is required on the comparative merits of the available systems (rotational crossbreeding and the use of crossbred bulls, which may be produced in two different ways). Present theoretical evidence suggests that the creation of new "synthetic" breeds is not the best option under prevailing lowland tropical conditions.

f. <u>Selection</u>

i. Evidence documented from purebred Holstein herds in the temperate regions of Mexico and Colombia shows a 20-28% increase in milk yield due to the use of imported semen from bulls proven by progeny testing to be of superior genetic quality for milk yield, compared with bulls of inferior quality. There was no marked difference in fertility or herd life.

ii. The importance attached to "type" (physical appearance) rather than production is an important obstacle to progress in performance traits in Latin America. The effect is passed down to the small farmer who relies on the "elite" herds for bulls or semen, and is obliged to pay part of the exorbitant cost of the progeny of high "type" bulls and cows. This tendency, which is supported by powerful commercial interests, is completely unacceptable in developing countries faced with the increasingly urgent task of producing more, cheaper food.

iii. In the lowlands tropics, differences between the best and the worst cows in European crossbred and zebu herds amount to 120 and 60% of the mean levels of milk production and calf weaning weights, respectively. This emphasizes the enormous scope for selection in these herds, provided that the "best" and "worst" animals can be correctly identified. For this to be possible, recording schemes must be extended and modified so that farmers are provided with objective information on which to base selection decisions. Methods should also be developed for selecting cows simultaneously for the traits which are important in each production system, since the traditional selection index is usually inapplicable under tropical conditions.

iv. The conditions under which bull selection by progeny testing is justifiable are very rarely met in the lowland tropics.

v. In the view of the difficulty of bull progeny testing, great importance is attached to:

- The development and implementation of adequate selection criteria for cows, so that outstanding animals can be used as bull dams, and
- Determining the genetic quality of sires of European breeds, progeny tested in temperate countries, which are most suitable for use in lowland tropical production systems, including those of dual purpose.

g. <u>Distribution of improved stock to farms</u>

i. The election of the best means of distributing improved livestock to farms should take into account that low reproductive efficiency is characteristic of most tropical herds and constitutes the main single factor limiting productivity.

ii. In this context, artificial insemination should generally be regarded as a strategic tool for genetic improvement. In most circumstances especially in the lowlands, it is not to be recommended as a routine means of producing pregnancies.

iii. Bull producing (nucleus) herds, run under strict technical supervision, offer many advantages as a source of improved stock, especially for small farmers. However, when these herds have been run by governments or other institutions, they have generally not been successful in Latin America. It is suggested that they should be organized by farmer associations with the necessary technical assistance.

iv. Embryo transfer is not at present a justifiable use of scarce resources for genetic improvement in developing countries.

TABLE 1. SWINE, GOAT AND SHEEP POPULATIONS IN THE WORLD AND THE TROPICS AND SUBTROPICS. 1986.
(in thousands)

	SWINE			SHEEP			GOATS			CATTLE		
	No.	%		No.	%		No.	%		No.	%	
-WORLD TOTAL	882 443	100		1 145 690	100		492 755	100		1 268 934	100	
-DEVELOPED Countries M.E. 1/	192 528	21.8		362 968	31.6		20 404	4.1		268 961	21.2	
-DEVELOPING Countries M.E. 1/	131 515	14.8	100	493 323	43.1	100	396 456	80.4	100	787 289	62.0	100
Africa	10 486		7.9	133 565		27.1	136 504		34.4	140 865		17.9
Latin America	81 507		61.9	117 544		23.8	31 651		7.9	317 608		40.3
Near East	310		.2	154 206		31.2	61 632		15.5	56 688		7.2
Far East	37 229		28.3	87 981		17.8	166 542		42.0	271.542		34.5
Other	1 982		1.7	28		0.1	127		0.2	586		.1
-CENTRALLY PLANNED	498 400	6.3		289 399	25.3		75 332	15.5		212 683	16.8	
-TOTAL DEVELOPED Countries	335 579		44.9	544 528		46.7	28 991		6.0	423 145		33.3
-TOTAL DEVELOPING Countries	486 864		55.1	611 162		53.3	463 201		94.0	845 789		66.7

1/ Market Economies

Source: FAO. 1986. Production Network. Food and Agriculture Organization of the United Nations.

TABLE 2. Distribution of scientific articles published on cattle in Latin American Journals in the period 1972-84, according to discipline and production system.*

Discipline	n	Percentage of total			
		Dual purpose	Specialized Dairy	Specialized Beef	General
Breeding	128	10	43	46	1
Nutrition	115	5	41	27	27
Pastures	98	0	7	2	91
Reproduction/ Physiology	93	26	32	31	11
Health	15	33	20	0	47
Economics	10	30	10	0	60
Management	7	29	43	14	14
Systems	7	29	14	43	14
TOTAL	473	12	31	26	31

* Journals reviewed: Memorias, Asociacion Latinoamericana de Producción Animal, Producción Animal Tropical, Agronomía Tropical, Congresos Venezolanos de Zootecnía I, II and III. Source: Vaccaro (1986).

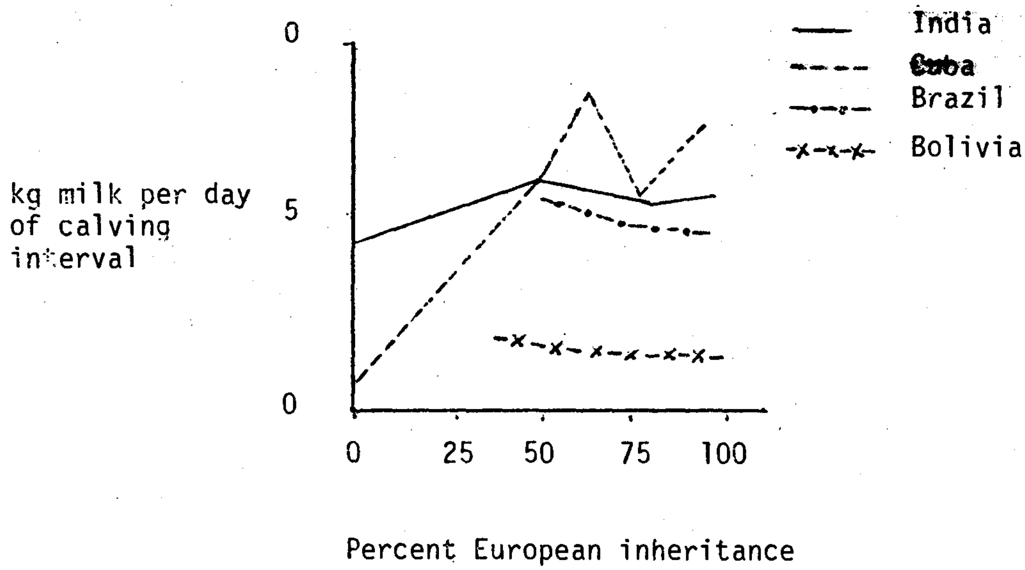

Figure 1: Relationship between the grade of European-zebu inheritance in crossbred cattle in four countries, and their production of milk per day of calving interval (Source: Vaccaro, 1987a)

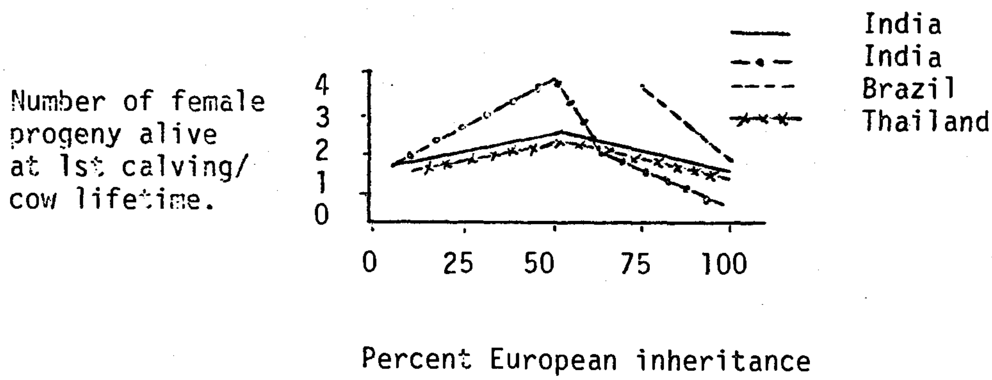

Figure 2: Relationship between the grade of European-zebu inheritance in crossbred cattle in three countries, and their production of heifer replacements per lifetime of the dam. (Source: Vaccaro, 1987a).

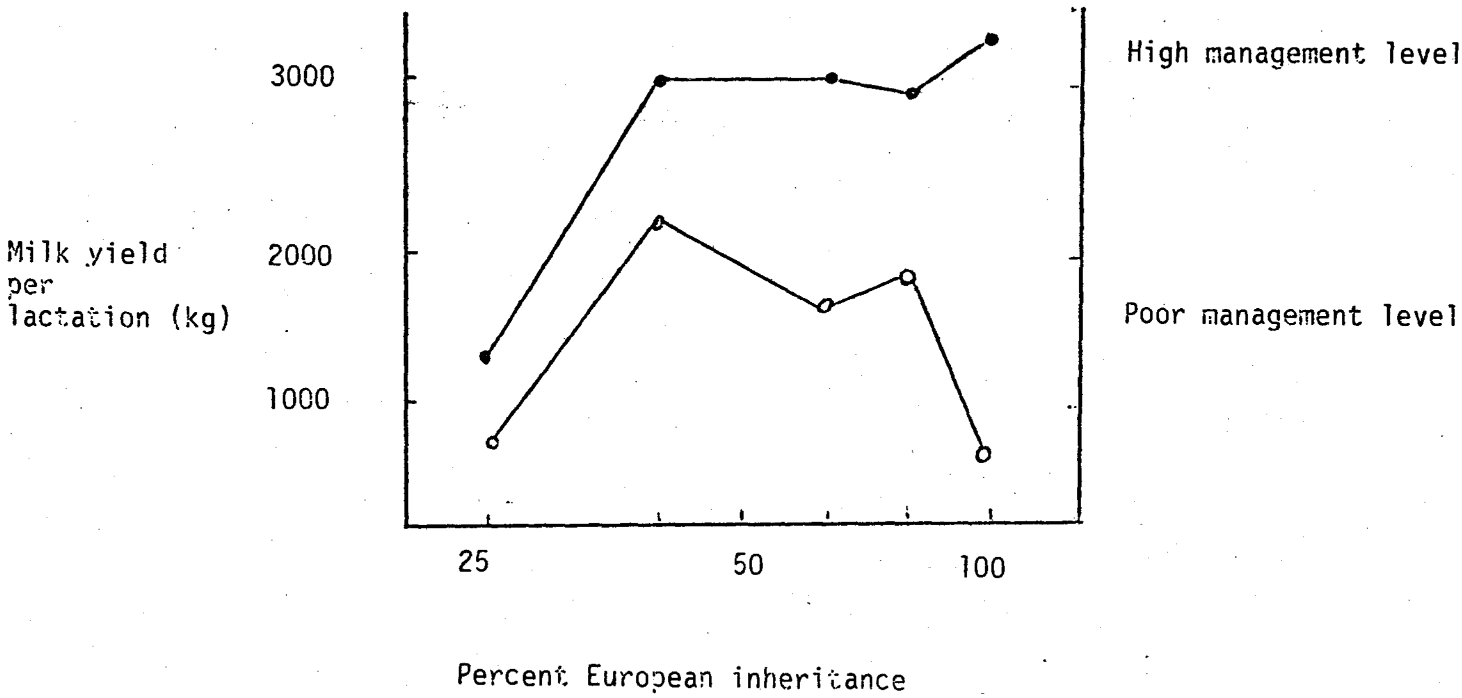

Figure 3: Relationship betwen grade of European inheritance and milk production under good and poor environmental conditions in Brazil (Madalena, 1983).

TABLE 3. Mean performance data of Holstein Friesian cows in commercial herds in temperate zones of Colombia and Mexico.

	MEXICO	COLOMBIA
Predominant Production System	Confined; maize silage+ fresh alfalfa; concentrate supplement. Altitude: 500-2200 m.	Grazing ryegrass, clover and kikuyu, little concentrate supplement Altitude: 2600 m
No. records	313102	24134
Milk yield/lactation (kg)	5272±2137	4281±1891
Lactation length (days)	268±65	267±68
Calving interval (days)	416±123	421±100
Age at first calving (months)	28.7±4.8	36.6±10.8

Source: Abubakar, 1985

TABLE 4. Productive performance of European and other breed groups on small farms in the lowland tropics of Bolivia.

	Genetic Group					
	Zebu/ Criollo	Criollo	1/4-Europ.	1/2-Europ.	3/4-Europ.	European
Milk Production cow (kg/year)	669	690	748	713	739	804
Calving %	92	79	87	83	72	64
Milk Production 100 cows/year (kg)	61548	54510	65076	59179	53208	51456

Source: Breinholt (1982)

TABLE 5. Productive performance of various genetic groups on 495 medium farms in Barinas State, Venezuela, and summary of prevailing management system.

	Genetic Group				
	Criollo	Zebu	Criollo x Zebu	European crossbreds	
				Low grade	High grade
Milk yield/cow (kg/day)	2.5	2.6	2.2	2.5	3.0
Annual calving percentage	78	63	69	66	64
Milk production/ 100 cows/year (kg)	48750	40950	37950	41250	48000

	%total herds
Manage herd in one unit	52
Hand milk with calf,1x/day	96
Keep production records	2
Feed some energy-protein supplement	6
Feed minerals (except salt)	23
Fertilize pastures	8
Conserve forage for dry season or irrigate	12
Control endoparasites	47
Control ectoparasites	64
Vaccinate against foot and mouth disease	74

	%total pasture area
Native grass	17
Hyparrhenia rufa	53
Cutting species	1

	% all farmers
Did not finish primary education	63

	Mean profitability (%)
15 sample farms	-3.0

Source: Cardozo et al. (1980).

TABLE 6. Milk yields obtained and required to cover costs by imported European and local crossbred cattle in Sta. Cruz, Bolivia.

		Milk yield (kg/cow/year)		
Production System	Genetic group	Obtained	Required to cover costs	Difference
Confined	European	3000	4200	-1200
Pasture+supplement	European	2400	3600	-1200
	Crossbred	2600	2000	+ 600

Source: Wilkins et al. (1979)

TABLE 7. Losses of European and high-grade crosses in intensive milk production systems in Venezuela.

	n			
	Farms	Animals	Range (%)	Weighted mean (%)
		a) Imported females		
Loss from:				
Arrival-1st calving	7	1217	4.2 - 22.9	11.6
Abortions	5	1605	3.7 - 11.3	7.5
Stillbirths	3	730	7.7 - 12.2	8.6
		b) Locally born females		
Birth -9 or 12 months	8	4278	13.4 - 81.3	17.7
9 or 12 mo.-1st calving	8	3577	8.1 - 30.8	21.1

Source: Vaccaro (1987b)

TABLE 8. Effects on yield and net income of the introduction of improved cattle in an integrated development project in Kerala, India.

Genetic group	Pasture System			Pasture+Supplement		
	Native	Improved	Increase (%)	Native	Improved	Increase (%)
Milk yield/cow (kg/lactation)	491	1144	133	454	1455	220
Net income/cow/ year (rupees)	298	621	108	223	876	293

Source: Patel et al. (1976)

TABLE 9. Examples of results of successful genetic improvement projects in the lowland tropics.

	Milk yield (kg)			**Fertility[2]**			**Calf Mortality**			**Net Income**		
Source	Local	Improved	%Diff.[1]	Local	Improved	%Diff.	Local	Improved	%Diff.	Local	Improved	%Diff.
1. Cuba[5]	500	2261	+ 352	450	392	+ 13	7.7	6.7	+ 13	-	-	-
2. Panama[6]	662	1247	+ 88	79	70	- 11	2.7	11.8	- 337	130 96	216 117	+ 66 + 21
3. India[7]	740	2188	+ 196	458	433	+ 5	4.4	9.6	- 118	-	-	-
4. India[8]	1772	2538	+ 43	421	432	- 3	22	0	+ 100	-	-	-

1. Difference as % mean local breed; sign denotes beneficial (+) or negative (-) change.

2. Fertility expressed as calving interval (days) or calving percentage (Panama).

3. Net income per hectare.

4. Net income per animal unit.

5. Cuba: zebu vs 1/2 Holstein - 1/2 zebu, state farms (Prada, 1978, 1979; Planas, 1979).

6. Panama: commercial herd with 84% European crosses, 16% zebu criollo vs herd 2 with 36% European crosses, 59% zebu-criollo (Seré et al., 1982).

7. India: local zebu vs 1/2 Brown Swiss - 1/2 zebu, experiment station, Kerala (Nair, 1973).

8. India: local Sahiwal (zebu) vs 1/2 Friesian - 1/2 zebu, military farms (Katpatal, 1977).

TABLE 10. Examples of the effects of various environmental factors on milk yields in lowland tropical cattle herds.

Source of variation/variable	Minimum	Maximum	Difference*as % of mean	Observations
HERD				
kg/cow/day	2.7	5.2	66	18 mixed farms, Veracruz, México
kg/cow/year	553	922	52	16 farms, Santa Cruz, Bolivia
kg/cow/lactation	450	900	60	19 herds, Northern Colombia
" " "	1517	4638	109	28 herds, Jamaica Hope cows, Jamaica
YEAR				
kg/cow/lactation	2678	3257	20	7 years, 28 herds, Jamaica
	3616	5762	56	6 years, 62 herds, Puerto Rico
SEASON				
kg/cow/day	2.0	3.2	43	Wet season dry season, Northern Colombia
	2.7	3.5	26	Wet season dry season, Barinas State, Venezuela
kg/cow/lactation	3819	3956	4	Dry season wet season, Puerto Rico
total sales/month (kgx10)	185	404	82	December February, Sta. Cruz, Bolivia
total sales/farm/day (kg)	40	69	51	Wet season dry, 6 herds, Panama
AGE OF COW				
kg/cow/lactation	619	796	23	5th and 6th lactations 1st, Northern Colombia
	2629	2978	12	Cows 60 months those under 37 months, Jamaica
	2447	4163	45	Cows 60 months those under 24 months, Puerto Rico
kg/cow/day	2.9	3.2	10	Adults heifers, 6 herds, Panama
MILKING SYSTEM				
Total milk/cow/lactation (kg)	2411	3183	28	Restricted suckling artificial weaning, Mexico
Saleable milk/cow/lactation (kg)	2021	2557	23	Restricted suckling artificial weaning, Mexico
" " " " "	322	701	74	Milking with calves without calves, Colombia

1 Aluja and Mc Dowell, 1984 · 2 Breinholt, 1982 · 3 Schellenberg, 1983 · 4 Schneeberger et al.(1982)
5 Camoens et al., 1976a · 6 Cardozo et al., 1980 · 8 Alvarez and Saucedo,1982 · 9 McDowell, 1971
7 Seré et al., 1982
* Difference between maximum and minimum values as % mean.

TABLE 11. Effects of environmental factors on traits other than milk yield in lowland tropical cattle herds.

Source of variation/variable	Minimum	Maximum	Difference* as % of mean	Observations
	a) REPRODUCTIVE EFFICIENCY			
HERD				
Calving percentage	59	100	51	16 farms, Santa Cruz, Bolivia
YEAR				
Calving percentage	36	96	95	2 years, 10 herds, Panama
Calving interval (days)	424	469	10	6 years, 19 herds, northern Colombia
SEASON				
Conception to 1st service (%)	55	66	18	Dry season wet, dual purpose herds, Zulia, Venezuela
AGE OF COW				
Conception to 1st service (%)	57	68	18	Heifers adults, dual purpose herds, Zulia, Venezuela
Calving interval (days)	395	513	27	1st 7+interval, northern Colombia
MILKING SYSTEM				
Calving interval (days)	389	429	10	Restricted suckling artificial rearing, Mexico
SERVICE METHOD				
Conception to 1st service (%)	60	72	18	AI Natural service, dual purpose herds, Venez.
	b) CALF SURVIVAL			
HERD/LOCALITY	0	59	295	6 herds, Panama
Calf death rate (%)	14	34	95	5 localities, 97 farms, SE Brazil
SEASON OF BIRTH				
Calf death rate (%)	12	22	67	Wet season dry, 1 stabled herd, Venezuela
AGE OF DAM				
Abortion rate (%)	4	9	-	Cows heifers, 6 herds, Panama
MILKING SYSTEM				
Calf mortality (%)	6	46	-	Artificial rearing restricted suckling, Mexico
	c) BODY WEIGHTS			
HERD				
Cow weight (kg)	315	422	29	10 herds, Panama
Calf weight 4 months (kg)	58	100	54	5 dual purpose herds, Venezuela
SEASON				
Cow weight (kg)	355	398	12	Dry start of wet, northern Colombia
Daily gain to 2 years (females, kg)	.19	.24	24	Females born wet season dry, 6 herds, Panama
MILKING SYSTEM				
Calf daily weight gain (kg)	.50	.62	20	Restricted suckling artificial rearing, Mexico

[1]Breinholt (1982) [2]Espinoza et al. (1986) [3]Schellenberg (1983) [4]Gonzalez (1981) [5]Alvarez and Saucedo(1982)
[6]Seré et al. (1982) [7]Filho (1973) [8]Vaccaro and Vaccaro(1981) [9]Vaccaro et al. (1986b)
Difference between maximum and minimum values as % mean.

TABLE 12. Example of the negative relationship shown between milk yield and fertility in crossbred European x zebu cows in dual purpose systems in the lowland tropics of Venezuela.

Milk yield/lactation (kg)	Interval from calving to conception (days)	% anoestrous cows
1000	68.1	17
1001 - 1500	92.6	22
1501 - 2000	104.7	28
2001 - 2500	121.6	42
2501 - 3000	137.4	57
3000	141.9	65

Source: Gonzalez (1980)

TABLE 13. Estimated genetic values for weaned calf weight of the five cows with highest estimated genetic values for milk yield in a dual purpose herd of crossbred European x zebu cows.

Ranking of cow for milk yield	Estimated genetic value (kg)	
	Milk yield	Calf weight
1	+ 364	-7
2	+ 331	-2
3	+ 274	-2
4	+ 249	-7
5	+ 233	-23 (calf died)

Source: Vaccaro et al. (1986)

TABLE 14. Performance in Mexico and Colombia of the daughters of bulls progeny tested as superior (high) or inferior (low) for milk yield in the USA and Canada.

	Estimated genetic values of sires for milk yield	
Performance of daughters in:	High*	Low**
COLOMBIA		
Milk yield (kg/lactation)	5197	4345
Calving interval (days)	470	441
% Completing 3 lactations	48	53
MEXICO		
Milk yield (kg/lactation)	7156	5607
Calving interval (days)	442	423
% Completing 3 lactations	46	50

* Mean predicted differences for "high" sires were 142 kg (Colombia) and 197 kg (Mexico).

**Mean predicted differences for "low" sires were -41 kg (Colombia) and -63 kg (Mexico) where predicted difference for milk is defined as the expected deviation of yields of the bulls' daughters from contemporaries' means in breed-average herdas.

Source: Abubakar (1985)

TABLE 15. Estimated genetic values* of bulls whose semen was imported into three Latin American countries.

	% bulls superior for:	
Country	Milk yield	Physical appearance
Mexico	44	81
Peru	45	32
Puerto Rico	46	65

* Based on predicted differences for milk yield per lactation and type. (see table 12 for definition).

Sources: McDowell et al. (1976); Vaccaro et al. (1979).

TABLE 16. Summary of a comparison of the performance of crosses derived from Holstein Friesian and Brown Swiss cattle, and local tropic breeds (based on 16 publications from 5 countries).

	Mean value of the crosses		% superiority of Holstein crosses
	Holstein Friesian	Brown Swiss	
Mortality and culling %:			
Calves	6.7	10.4	36
Heifers	10.9	13.3	18
Cows	25.7	26.3	2
Body weight (kg)			
6 months of age	110	100	10
18 months of age	279	225	24
Age at 1st calving (months)	33	35	5
Calving interval (days)	420	428	2
Milk yield (kg/lactation)	2275	1965	16

Source: Vaccaro (1984).

TABLE 17. The importance of selection in commercial dual purpose herds: deviations from contemporary means of the records of the best and worst cows in five herds of crossbred (European x zebu) and zebu cattle in the lowland tropics.

Herd No.	Milk yield/lactation (kg) Best	Milk yield/lactation (kg) Worst	Calf weaning weight (kg) Best	Calf weaning weight (kg) Worst
1	3058	- 1694	52	- 27
2	922	- 861	38	- 37
3	1175	- 1096	42	- 18
4	1484	- 1391	26	- 24
5	1634	- 1215	39	- 22

Source: adapted from Vaccaro et al. (1986a).

3.1 SHEEP

3.1.1 Background

Sheep production around the world occurs under two environmental conditions. Hair sheep are raised in tropical and sub-tropical areas of the world; while, wool sheep are mainly raised in temperate zones. In the first case, hair sheep have a similar ecological and systems distribution to goats. The total world population of hair sheep is about 100 million head, distributed over Africa, the Caribbean region, Brazil, India and South Eastern Asia, comprising about 10% of the world sheep population. Their body cover with hair, instead of wool, provides an adequate physiological adaptation to tropical environments and in general their appearance is similar to goats. The principal products from hair sheep flocks are the sale of live animals and those used for family consumption. Hides are an important by-product.

Wool sheep represents 90% of the sheep population of the world, of about 1.1 billion head. They are distributed mainly in temperate countries, but are also found in semi-tropical environments and in the hight altitude regions of tropical countries. The primary purpose under extensive commercial operations is the production of wool, with mutton as a by-product. In many developed countries, due to the restriction of land, sheep are raised under intensive management with the primary objective of producing mutton.

Hair sheep are found in farming systems similar to those described in the next section for goats. They are part of extensive production systems, common to North East Africa and South America. In the Caribbean region, hair sheep are raised tethered as part of mixed farming systems. Under small farm conditions, wool sheep are kept in small flocks either as part of a pastoralist system or combined with crops in mixed systems.

Animal breeding goals for the wool sheep population have been clearly defined. Breeding practices have brought substantial genetic improvement in wool and mutton production under commercial operations. This type of sheep raised under small farm conditions have goals similar to those described in the preceding chapter for swine. They are primarily a means of saving, as well as providing fertilizer, meat and wool for family consumption. Under these conditions no emphasis has been placed in either growth rates for body weight or wool. Thus, this situation requires a careful analysis of the socio-economic conditions in which wool sheep are raised, in order to define those productive traits that will be target of breeding programmes.

Information on hair sheep will be presented in the next sections for tropical regions, while some inferences from wool sheep will be drawn to analize small farmer sheep raising in temperate zones. Hair sheep have had the attention of the scientific community over the last 10 years as source of genetic material for prolificacy, but small farm wool sheep have received limited attention.

3.1.2 Identification of Most Productive Breed Groups

Tropical hair sheep breeds have been the subject of several publications over the last 7 years (Mason, 1980; Gonzalez, 1985; Fitzhugh and Bradford, 1983), and extensive description of sheep breeds and their productive parameters have been compiled. One of the most important characteristics is prolificacy and hair sheep have been used in crosses in developed countries to increase litter size in intensive mutton producing operations. Breeds have been characterized by several parameters and those that have received most attention are: West African, Pelibuey, Barbados Black Belly, Black Headed Persian, Santa Ines, Morada Nova, Somali, and the Africana. Published material provides abundant information on breed and productive characteristics under different environmental conditions (Mason, 1980; Fitzhugh and Bradford, 1983).

In many of the tropical countries, a Criollo type hairsheep exists together with the clearly identified breeds described in the preceeding paragraph. This Criollo has particular characteristics in different countries: isolation and natural selection have produced characteristics that in many cases can set them apart as breeds (Cheng, 1984; Gonzales, 1985; Maule, 1977). Wool sheep from developed countries have been introduced into the developing world for commercial operations and small farmer systems. Breeds such as the Merino, Rambouillet, Corriedale, Romney Marsh, Columbia, Panama, etc. have found different niches of adaptation in several developing countries. Information on their productivity is presented in Tables 18 and 19. In Table 18, Alderson _et al_, (1982) evaluated in Colombia the performance of Rambouillet, Corriedale, American and British Romney and Criollo Sheep from Colombia. Performance traits are presented in Table 18. Even though the Criollo sheep have lower weight and wool yields, survival and birth rates offset these differences. Thus, in an overall evaluation, the Criollo animal compares favourable with the imported breeds.

In Table 19, production parameters from Corriedale, Junin and Criollo sheep from Peru are presented. In this case, a productive advantage is evident for the Corriedale and Junin over the Criollo. However, no general evaluation was made of the Criollo, in which reproductive and survival rates were included. Comparing data from Peru and Colombia, a superiority for the Corriedale and Junin breeds in Peru over the breeds tested in Colombia is apparent, Corriedale and Junin sheep are raised on high altitude natural ranges with no supplemental feeding.

Evaluation of these breeds might help the selection of breeds for commercial oriented operations and also indicates that Criollo sheep may have the genetic potential to compare favourably with exotic breeds in some environmental conditions. Additional evaluations are underway in two areas of Peru, with the object of obtaining lifetime productive and genetic parameters, but only preliminary results have been published to date (Lencinas et al, 1984).

In selecting wool breeds, and breeding programmes for them, careful considerations must be given to the case of the small farmer. Wool has home uses, and its quality and characteristics can be different from those applicable in commercial operations. The introduction of exotic breeds might change fleece characteristics, making them unsuitable for handcrafts or homemade fabrics (Blackwell, 1983). In this case a study of the socioeconomic factors of sheep production is required to define breeding goals for wool characteristics and quality.

3.1.3. Environmental Factors that Affect Productive Performance

Environmental factors identified in wool sheep production include year, season of birth, sex, type of birth and age of dam. Some of these estimates have been obtained in developing countries in commercial sheep operations (Burfening et al, 1981; Cabrera et al, 1982; Huapaya, 1985; Montesinos, 1983).

There are no estimates available on environmental factors for small farmer production systems. However, year and season of birth will probablyhave strong influences on survival and productive performance, especially with the all year round breeding which is practiced by small farmers. This is an area in which futher studies are needed.

In tropical hair sheep, age of dam, parity season and year are factors affecting reproductive and productive performance (Fitzhugh and Bradford, 1983; Gonzalez 1979; Mason, 1980). Fitzhugh and Bradford (1983) have identified some constraints common to hair sheep production systems. They include: ecological and environmental limitations, biological constraints (nutrition, health and genotype) and socioeconomic constraints (labor, management and market demand). As in wool sheep, these environmental factors have to be taken into account in defining breeding programs.

3.1.4 Genetic Parameters of Productive Traits

Heritabilities and genetic correlations reported for wool sheep from developed countries are presented in Tables 20 and 21. Table 20 presents repeatabilities and heritability estimates for productive traits in high fertility crosses with Finn sheep. Characteristics associated with litter size and survival are located in the low range of heritabilities. In Table 20 phenotypic and genetic correlations for selected traits in developed countries are presented.

Parameters for fleece traits are presented in Table 22. These values represent a compilation by Turner (1956) from different sources from sheep operations in the developed world. These characteristics are of a particular economic value for wool exporting countries, and have direct relationship with standards of the textile industry.

Estimates from Peru include: heritabilities of .58 ± .07 for liveweight at 12 months; .20 ± .09 fleece weight and .03 ± .02 for staple length (Diez et al, 1973). Additional estimates by Huapaya (1985) are of: .31 + .002 for birth weight; .13 + .001 for weaning weight; .11 + .001 for 16 months weight and .32 + .001 for staple length in Junin sheep. Estimates for Corriedale and Junin x Corriedale are of similar values (Cabrera et al, 1982; Montesinos, 1983).

No reports have been found on genetic parameters for hair sheep, even though abundant information has been published with regard to productive traits (Mason, 1980; Fitzhugh and Bradford, 1983).

3.1.5. Response to Genetic Improvement Programmes

a) Selection Results

Selection results have been published in Peru for wool sheep under mass selection in a closed herd of Corriedale sheep. Montesinos (1983) reported increases of 5% for body weight and 3% for fleece weight yearly after three years of selection. Selection involves an index with an economic weight of 70% for body weight and 30% for fleece weight, which represents the situation prevalent in wool operations in Peru.

These are no estimates of genetic parameters in Criollo wool sheep and also no estimates available for tropical hair sheep.

Selection has been successfully used for the formation of a Synthetic breed of wool sheep in Peru based on the Criollo, Corriedale, Romney Marsh, Columbia, Panama and Warhill breeds. After 40 years of mass selection of the closed herd for weight and wool traits the Junin breed was created in the Central Highlands of Peru (Alvarez Calderon, 1965; Villarroel and Gamarra, 1978). It is estimated that close to 10% of the commercial sheep in Peru are of the Junin breed. It is well adapted and achieves satisfactory levels of production in the natural range environment of the Andean Mountains. Several reports (Burfening et al, 1981; Cabrera et al, 1982; Huapaya, 1985) have presented productive and genetic parameters for this breed. Crossbreeding studies of Junin x Corriedale crosses have shown an adequate amount of heterosis for weight and wool traits (Cabrera et al, 1982).

Since fertility and litter size at birth are traits of great economic importance in commercial sheep operations in the developed world, substantial attention have been given to selection within breed for these traits. A recent, fairly complete report on selection results for litter size and reproductive efficiency has been presented by Land and Robinson (1985). The uses of Finn sheep, Romanov, Chios and Booroola-Merino are presented and discussed including their implications for improving litter traits through crossbreeding and selection schemes.

It is apparent that there is enough genetic variability in fertility and litter size, for these traits to be included in selection or crossbreeding programmes in developing countries. However, the levels of performance obtained from selected breeds are associated with intensive management and nutrition, normally not found in small farm systems. Many breeds of tropical sheep present the same fertility and high litter size characteristics useful to improve production.

b) Crossbreeding Results

Performance of single breeds and crosses of hair sheep are presented in Tables 23 and 24. Crosses have the normal advantage of heterosis in litter size and weight traits. More extensive studies and results on hair sheep crossbreeding have been presented by Fitzhugh and Bradford (1983).

Crosses between Junin and Corriedale have produced adequate results for weight and wool traits (Cabrera et al 1982), and crosses between improved breeds and Criollo sheep have improved body weight and fleece yield in semi-intensive commercial operations. Even though improved breeds are normally introduced to small farming systems, no reports have evaluated their impact on production. This is an area in which there is a substantial need for additional information.

TABLE 18. AVERAGES BY BREED AND SEX FOR BIRTH WEIGHT, WEANING WEIGHT AND SURVIVAL

		Breeds				
Trait	**Sex**	**Rambouillet**	**Corriedale**	**American Romney**	**British Romney**	**Criollo**
Birth weight, kg	M	4.20	4.01	3.57	4.25	3.55
	F	3.99	3.77	3.31	4.02	3.33
Survival from birth	M	.75	.82	.81	.93	.93
to weaning (%)	F	.81	.88	.83	.94	.93
Weaning weight (kg)	M	18.95	17.44	16.75	20.55	16.80
	F	18.41	16.77	16.63	19.53	14.93
Average daily gain	M	.123	.110	.109	.135	.110
(kg/day)	F	.119	.107	.110	.129	.096

Source: Alderson *et al* (1982)

TABLE 19. SUMMARY OF SOME PRODUCTION PARAMETERS IN WOOL SHEEP IN PERU

	Breeds		
Productive Traits	**Criollo**	**Corriedale**	**Junin**
Birth weight (kg)	3.39±.06	3.70±.03	3.81±.06
Weaning weight (4-5 months), kg	16.70±.43	24.48±.22	21.50±.37
8 month weight (kg)	19.63±.38	26.30±.19	29.41±.50
Adult ewe weight (kg)	28.13±.50	36.25	38.51±.21
Fleece weight 8 months (lb)		2.96±.10	3.12±.07
Length Staple adult (cm)		3.77±.007	10.53±.04

Source: Modified from: Huapaya (1985)

TABLE 20. REPEATABILITY AND PATERNAL HALF-SIB HERITABILITY ESTIMATES (± s.e.)

	Repeatability	**Heritability**
Fertility	0.06±0.01	0.06±0.02
Litter size	0.08±0.02	0.11±0.04
Perinatal survival	0.15±0.02	0.02±0.04
Postnatal survival	0.11±0.02	0.07±0.04
Mean weaning weight	0.13±0.03	0.10±0.05
Lambs weaned/ewe joined	0.05±0.01	0.03±0.02
Weight weaned/ewe joined	0.05+0.01	0.06+0.02

Source: Young *et al* (1985)

Table 21. PHENOTYPIC (ABOVE DIAGONAL) AND GENETIC (BELOW DIAGONAL) CORRELATIONS FOR SELECTED TRAITS.

	Fertility	**Litter size**	**Perinatal survival**	**Postnatal survival**	**Mean weaning weight**	**Lambs weabed**	**Weight weaned**
Fertility		0.03	0.03	-0.02	-0.01	0.61	0.61
Litter size	-0.34		-0.15	-0.20	-0.38	0.26	0.13
Perinatal survival	-0.22	-0.30		0.08	0.06	0.34	0.35
Postnatal survival	-0.09	-0.32	0.78		0.16	0.55	0.58
Mean weaning weight	0.18	-0.39	1.42	-0.26		-0.14	0.23
Lambs weaned	0.30	0.04	0.68	1.60	0		0.94
Weight weaned*	0.58	-0.02	0.49	0.91	0.41	1.05	

*per ewe joined.

Source: Young *et al* (1985)

TABLE 22. ESTIMATES OF HERITABILITY FOR FLEECE WEIGHT AND ASSOCIATED CHARACTERISTICS, MEASURED AT YEARLING AGE (12-18 MONTHS)

Characteristic	Range within which most heritability estimates fall
Greasy fleece weight	0.3 - 0.5
Clean wool weight	0.4 - 0.6
Body weight	0.3 - 0.5
Staple length	0.3 - 0.6
Fibre diameter	0.2 - 0.5

Source: Turner (1956).

TABLE 23. HAIR SHEEP BREED AVERAGES FOR PRODUCTION TRAITS

Trait	Pelibuey, West African	Virgin Islands	Barbados Blackbelly	Blackhead Persian	Forest
Litter size, No.Lambs	1.24	1.61	1.84	1.08	1.22
Lambing interval, days	245	248	248	248	284
Lamb survival	0.79	0.78	0.78	0.65	0.72
Birth weight, kg	2.5	2.7	2.7	2.4	1.7
Ewe weight, kg	34	35	40	27	27
$W^{.75}$	14.1	14.4	15.9	11.8	11.8

Average for Barbados Blackbelly substituted for unknown value.

Source: Fitzhugh and Bradford (1983)

TABLE 24. BODY WEIGHT OF BARBADOS BLACKBELLY AND CROSSES.

	Body weight (kg)		
Breed & Crosses	**Birth**	**Weaning**	**6 month**
Blackbelly x Criollo	2.67	13.6	18.1
Blackbelly x (Blackbelly x Criollo)	2.67	12.4	16.7
West African x Criollo F	2.65	14.3	19.7
West Africa x (West Africa x Criollo)	2.81	11.8	16.9
Blackheaded Persian x Criollo F	2.78	13.1	17.0
Blackheaded Persian x (Blackheade Persian x Criollo)	3.01	13.9	19.3
Blackbelly x West Africa	2.53	14.2	2.10
Blackbelly x Criollo x West Africa x Criollo	2.45	14.0	19.8

Source: Mason (1980)

3.2 GOATS

3.2.1 Background

Over 85% of the world's goat production takes place in developing countries. Goats are widely used by small farmers in a range of different ecologies and in many different farming systems. In comparison with swine and sheep, commercial goat production in developed countries is fairly limited in size and scope. Over the last 15 years a large body of publications and studies from developing countries has increased the knowledge on goat production. Even though some of the most productive breeds have been developed in Europe, studies on native and local breeds all over the world have evaluated their genetic potential either as purebreds or in crosses with exotic animals.

Devendra (1981) has characterized the world's most important goat production systems. A summarized version is presented in Table 25. Four major systems have been characterized. The first one is goat raising with tethered animals, common to sub-humid and humid areas of Asia and Africa. One of the most common systems is the extensive one, using rangelands, shrubs, and deciduous vegetation in the arid and semi-arid areas of Asia, Africa and America. Also associated with this systems are the dry highlands of the Near East, Himalayas and the Andes. Intensive production systems are common in the sub-humid and semi-arid areas of the south east Asia, the Near East and Africa. Finally, goats are used in mixed systems in parts of South East Asia, East and West Africa and the Near East.

Goats are used mainly as producers of meat, milk and skins. The emphasis on any of these products will be related with the ecological area, nutritional resources available and the socioeconomic requirements of the famers.

Even though goats are so prevalent on small farms, in contrast to swine, a clearer definition of the productive objectives are evident in the different systems of goat production. This is particularly true in extensive systems in which pastoralist, in many cases nomadic, farmers will have livestock as their only means of economic support. Thus the system tends towards a consistent, commercial production of livestock products for maintenance and income. This fact might help define the economic objectives of goat production more clearly, and facilitate the definition of breeding objectives. On the other hand, in view of th large populations and economic importance of goats in developing countries, many of them have started their own programmes often directly oriented to the needs of farmers.

3.2.2 Identification of Most Productive Breed Groups

Due to the characteristics of goat production described above, a fairly clear identification of productive breed groups in developing countries has been made. There is also a good deal of information on the productive potential of exotic breeds, under the conditions of developing countries.

Table 26 presents a list of some outstanding indigenous goat breeds evaluated in developing countries (Devendra, 1981). The largest groups of breeds are from India, Pakistan, the Middle East and Africa. Productive potential includes milk production, meat, skins, fibre and as an added productive trait, prolificacy. Devendra (1985) identified the litter sizes in prolific breeds of goats, dividing them into non-seasonal breeders, seasonal breeders and European breeds in the tropics (Table 27). Litter size at birth has a range of 1.05 for Saanen breed in Egypt to 4.5 for the Ma T'ou breed of China. Normal ranges for prolificacy are from 1.7 to 2.10 kids at birth.

Thus, goats have the added advantage of prolificacy as a common trait in native and improved breeds providing an ideal tool for increasing production and productivity especially for meat production. This factor gives an special advantage to goats over cattle in terms of reproductive efficiency and biomass production in relation to metabolic weight (French, 1970).

The identification of outstanding breed groups of goats has been published by Acharya, (1987), Ashmawi, (1982); Constantinou and Mavrogenis, (1987); Devendra, (1985); Mecha and Agunwanba, (1982); Mittal, (1987); Rattner, (1987); Singh and Basuthaur, (1982); Steinbach, (1987) and Wilson, (1982). This body of information provides an adequate base for selecting specific breed groups within countries as a basis for breeding programmes.

Some important characteristics of these selected breeds for meat production are presented in Table 28. A special evaluation is made for total dressed weight, comparing prolific and non prolific breeds. There is a sustancial advantage for prolific breeds in terms of total meat output, and even though birth weights are lower in the prolific breeds, post-weaning growth as a compensatory effect minimizes differences at 12 month of age.

Other evaluations on local or criollo breeds of goats are presented in Tables 29 and 30. In Table 29 the prolificacy of criollo goats in two herds under extensive production systems in Peru is presented. With no supplemental feeding, the incidence of twinning ranges from 46.3% to 60.2% and of triplets from 36.7% to 25.3%. Single births occurred in only 17.0% and 9% of cases, respectively. Data on the milk production from criollo goats in Peru are presented in Table 30. Even though total milk yields are below those reported in improved European breeds, this table shows the potential of criollo animals under semi-intensive conditions for providing adequate amounts of milk for small farmers (Quijandría, 1982, 1984).

Additional information about production and productivity for selected breeds of goats will be presented in the crossbreeding section.

Imported breeds from developed countries have shown adequate performance under intensive and semi-intensive production systems in developing countries. The most common breeds imported as source of genetic material are the Toggenburg, Saanen, Alpine, Granadina, Murciana, Anglo Nubian and Nubian. These breeds of European or African origin are the basis for either pure breed milk production or grading up local breeds in several developing countries.

In Tables 31 and 32, milking characteristics of a group of exotic breeds, evaluated in Honduras, Central America are presented (CATIE, 1987). As in other areas of the world, the Alpine and Saanen goats produce the highest yields of milk, findings verified in other regions of the world by several reports (Acharya, 1987; Chawla and Nagpal, 1982; Gonzalez, 1979; Mukherje et al,1982; Nagpal y Chawla, 1987; Rana et al, 1982; Souza, 1987; Wahid et al, 1987).

In general, several studies have evaluated the importance of exotic and native breeds in developing countries, have identified potentially useful productive traits and constitute an adequate source of information for breeding programs. However, in selecting adequate breeds for goat improvement, availability of animals within a given area and adequate evaluation of their productive performance under a given environment is the principal factor for success.

3.2.3 Environmental Factors that Affect Productive Performance

The environmental factors that affect body weight and milk production of goats have been clearly identified (Acharya, 1987; de Souza *et al*, 1987; Quijandría, 1982; Gonzalez, 1979; Khan and Sahni, 1982; Meza-Herrera *et al*, 1987; Mukherje *et al*, 1982). The most clearly identified environmental factors are: year/season of birth, sex, type of birth, litter size, parity and age of dam. Lactation yield is normally affected by season of breeding, parity, lactation length and age at first kidding (Acharya, 1987). While body weights are affected by sex, season of birth, litter size, parity and age of dam (de Souza *et al*, 1987; Khan and Sahni, 1982; Meza-Herrera *et al*, 1987; Wahid *et al*, 1987).

As in other small animal species the plane and level of nutrition play an important role in determining production and productivity. Feed resources will affect litter size, kid survival and milk production, especially, in systems located on natural ranges in semi-tropical areas. In some cases, when the rainy season is favourable and pasture abundant, producers will emphasize milk production over meat, while under limited nutritional supply meat production will be given priority, does will not be milked and kids will have the limited supply of milk available for growth (Quijandría, 1984).

The effects of parity and type of parturition on total milk production, lactation length and average daily production are illustrated in Table 30.

3.2.4 Genetic Parameters of Productive Traits

Genetic Parameters: heritability and genetic correlations for goats have been calculated in several developing countries for a large number of breeds (Constantinou and Avrogenis, 1987; Meza-Herrera *et al*, 1987; Nagpal and Chawla, 1987a, b); Devendra (1981, 1982) has summarized heritability estimates from several sources for litter size, Taneja (1982) published a summary of repeatability and heritability estimates for multiple births and Acharya (1987) has compiled heritability estimates for weight and lactation traits in India.

In Tables 33 and 34, a summary of heritability estimates for litter size and multiple births are presented. Estimates are somewhat above those found in other species, with values that ranges from 0.01 (low) to 0.25 (medium). Some of these estimates suggest that there exists genetic variability for litter size that can be used in selection programmes.

Heritabilities for growth traits are presented in Tables 35 and 36. With the exception of reports by Ribeiro and Santos (1987), in which values are fairly low for weight traits, heritability estimates range from 0.15 to 0.91. The highest values estimated are from India by Nagpal and Chawla, (1987). In Table 36 genetic and phenotypic correlations between weight traits are also presented. There is a negative correlation between weight at birth and at 6 and 12 months of age. Otherwise, the magnitude of the genetic and phenotypic correlations in accordance with those reported for other species.

In Table 37, estimates of heritability and genetic correlations for lactation traits are presented (Acharya, 1987). The heritability estimates for lactation yield is .32 and for lifetime production .30. Both estimates indicate that appropriate selection schemes can be successful in increasing these traits. Genetic correlations between lactation traits follow patterns similar to those reported in dairy cattle. It has been reported (Mukherje et al, 1982) that selection for increased milk production reduces reproductive efficiency, a phenomenon that has also been reported in dairy cows. It is apparent that once a certain biological treshold is crossed in milk production, reproductive efficiency starts declining (Acharya, 1987; Mukherje et al, 1982). This problem is mainly associated with intensive dairy production, and has not been reported in either semi-intensive or extensive milk production systems.

The available estimates of genetic parameters in different breeds and countries provides an adequate base for breeding programmes. However, the constant modification of genetic variances in populations subjected to selection, requires the periodic re-evaluation of genetic parameters, and the compilation of data directly from farmers to calculate genetic parameters for farm-level goat production is also required.

3.2.5 Response to Genetic Improvement Programs

a) Selection Results

Even though selection programmes have been started in several countries in Africa, Asia and Oceania, limited information has been reported to date. Acharya (1987) reported selection results for milk production in India. The breed under selection was the Beetal, and the genetic trends reported for the selected population are 5.34 $\pm$ 4.98 days for age at first kidding, 1.62 $\pm$ 0.94 kg for first lactation milk yield, 0.01 $\pm$ 0.02 kg for average daily milk production, and 2.01 $\pm$ 1.22 days for first kidding interval. The Beetal flock under study was a closed one and selection was for milk production. Sire evaluation was based on progeny performance.

However, initial evaluations showed that the majority of sires used were of inferior genetic value and it was concluded that adequate evaluation of sires has to be made before a selection programme can be put into operation.

No reports have been found on selection for body weight and it appears that most of the work to improve meat traits is done through crossbreeding.

b) Crossbreeding Results

In Tables 38 and 39 results from crossbreeding experiences for milk production in India are presented. Table 38 presents the results of crosses between Alpine, Saanen and Beetal goats.

First lactation yields of the crossbreds were considerably higher than those of the Beetal and sometimes also higher than those of the exotic breeds. The yields ranged from 148.5 kg for the Beetal to 318.8 kg for the Saanen x Beetal crosses. Lactation length varied from 196.5 days for the Beetal breed to 264.6 days for the Saanen x Beetal.

In Table 39, data from crosses between Alpine, Saanen and Malabari goats are presented. It can be appreciated that 120 day yields are far below those for the Beetal breed presented in Table 38. Crosses show some improvement in milk production and the Saanen crosses are apparently superior to the crosses with Alpine. Interbreeding of half breds resulted in a substantial decline in milk production and 3/4 Malabari animals did not show any superiority over the half breeds. Saanen x Malabari crosses had poorer reproduction rates and, in general, the crosses showed a decline in reproductive performance compared with the purebred Malabari (Acharya, 1987).

Grading-up native low milk producers through crosses with selected indigenous breeds has brought substantial improvement in lactation yield and length in India (Acharya, 1987). Up-grading programmes have used the Beetal and Jamnupari breeds on medium and small size farms. Information to date indicates that the Beetal's performance is superior.

Crossbreeding for body size has been carried out with the European dairy breeds. Due to larger body sizes, all crosses have shown superiority in gains and weights at different ages. Also, crossbreeding with native breeds (Beetal and Sirohi) has improved performance under semi-intensive feeding regimes (Singh and Basathakur, 1982).

Reports in various countries (Angwenyi and Cartwright, 1987; Bhatnagar, 1982; Figueiredo et al, 1982, Mukherje, 1982, Patil and Koratkar, 1987; Rana et al, 1982, Sahni y Chawla, 1982, Chawla, 1982, Taneja, 1982) have shown that adequate crossbreeding schemes can increase both milk and meat production considerably. However, in many cases the selection of local and improved breeds, and the orientation of the system in which they will be used have proved important to the success of crossbreeding programmes.

As in other species, the formation of multiplier herds of native and/or exotic breeds constitutes an important step in organizing extensive improvement through crossbreeding.

TABLE 25. TYPES OF PRODUCTION SYSTEM AND TARGET ECOLOGICAL ZONES CONCERNING GOAT PRODUCTION IN THE DEVELOPING COUNTRIES.

Type of production system	Target ecological zone*	Region	Production Objective
Tethering	Sub-humid, humid (1200 mm)	South East Asia, West Africa	Meat, milk, skins
Extensive	Acid (500 mm)	North and North East Africa	Meat, milk
	Semi-arid (500-1200 mm)	North, Central & South America, Near East	
	Highlands	Alti-Plano, South America, East Africa, Near East, Himalayas	Meat, fibre
Intensive production	Sub-humid, humid (1200 mm) Semi-arid (500-1200 mm)	South East Asia Near East, Africa	Meat, milk skins
Integration with cropping systems	Semi-arid (500-1200 mm) Sub-humid, humid (1200 mm)	South East Asia, East and West Africa, Near East	Meat

* Figures within parenthesis indicate approximate annual rainfall.
Source: Devendra (1981)

TABLE 26. SOME OUTSTANDING INDIGENOUS GOAT BREEDS IN THE DEVELOPING COUNTRIES.

Breed	Speciality	Country of origin
Barbari	Milk, meat, prolificacy	India, tropical, dry
Beetal	Milk	India, tropical, dry
Black Bengal	Prolificacy	India and Pakistan, tropical, dry
Criollo	Meat	Central America, tropical, dry
Damani	Milk	Pakistan, tropical, dry
Damascus	Milk, prolificacy	Syria, sub-tropical, dry
Dera Din Panah	Milk	Pakistan, tropical, dry
Fijian	Meat	Fiji, tropical, humid
Jamnapari	Milk, meat	India, sub-tropical, dry
Kamori	Milk, meat	Pakistanm, sub-tropical, dry
Kambing Katjang	Meat, prolificacy	Indonesia, and Malaysia, tropical, humid
Kashmiri	Fibre (pashmina)	India, sub-tropical, humid
Malabar	Milk, prolificacy	India, tropical, humid
Maltese	Milk	Malta, sub-tropical, dry
Marwari	Milk	India, tropical, dry
Ma'tou	Prolificacy	China, sub-tropical, humid
Mubende	Skin	Uganda, tropical, humid
Nubian	Meat, skin	Sudan, tropical, dry
Red Sokoto	Skin, meat	Niger, tropical, humid
Sirohi	Meat	India, tropical, dry
West Africa dwarf	Meat, prolificacy	Nigeria, tropical, humid

Source: Devendra (1981).

TABLE 27. LITTER SIZE IN PROLIFIC BREEDS OF GOATS

Breed	Location	Litter size (kids/birth	Reference
(1)Non-seasonal breeders			
Barbari	India	1.84	Sachdeva et al. (1973)
Black Bengal	India	2.09	Moulich et al. (1966)
	Bangladesh	2.31	Rahman et al. (1977)
Criollo	West Indies	2.11	Devendra and Chenost (1973)
Katjang	Malaysia	1.60-1.90	Rajendram and Pillai (1976)
Ma T'ou	China	4.50a	Epstein (1969)
Sudanese Desert	Sudan	2.10a	Wilson (1976)
West African Dwarf	Ghana	1.90	Vohradsky and Sada (1973)
(2)Seasonal breeders			
Beetal	India	1.91	Amble,Khandekar and Garg(1964)
	India	1.70	Bhatnagar,Sharma and Mishra (1976)
	India	1.70	Chawla,Bhatnagar and Mishra (1982)
Damascus	Cyprus	1.76b	Constantinou (1981)
	Lebanon	1.65	Choueri (1973)
Malabar	India	1.70	Sundarsanan and Raja (1974)
	India	1.64	Mikundan and Rajagopalan (1971)
Zaraiby	Egypt	1.84	Shalash et al. (1970)
(3)European breeds in the tropics			
Alpine	South Africa	1.63	Hofmeyer (1972)
	India	1.90	National Dairy Research Inst. (1976)
Anglo-Nubian	Egypt	1.90	Shalash et al. (1970)
	India	1.62	Gill and Dev (1972)
	West Indies	1.80	Devendra and Chenost (1973)
Saanen	French West Indies	1.80	Chenost and Geoffroy (1973)
	South Africa	1.73	Hofmeyer (1972)
	Egypt	1.01	Shalash et al. (1970)
	Israel	1.90	Epstein and Hertz (1964)

[a] Per goat per year [b] Includes deaths

Source: Devendra (1985)

TABLE 28. BIOMASS PRODUCTION BETWEEN PROLIFIC AND NON-PROLIFIC GOAT BREEDS

Breed	Location	Birth weight (kg)	Live weight of males at 12 months (kg)	Live weight increase per day (g)	Dressed weight (kg)[c]
(1)Non prolific breeds					
Boer	South Africa	3.7[a]	22.6	52	8.8
East Africa	Uganda	2.6	15.9	36	8.0
Fijian	Fiji	2.6	16.4	39	7.0
Ganjam	India	2.3	17.7	42	5.9
Jamnapari	India	4.0	28.1	66	9.1
Kampri	Pakistan	2.7	17.0	39	8.5
Moxoto	Brazil	2.5	18.6	44	5.2
Mubende	Uganda	2.1	20.2	50	10.1
Native	Philippines	1.6	14.0	34	6.0
Sirohi	India	2.0	16.3	39	8.2
Mean		2.6	18.7	44	7.7
(2)Prolific breeds					
Anglo-Nubian	West Indies	2.9[b]	24.6	59	23.4
Barbari	India	1.8	14.9	36	13.7
Beetal	India	2.7	19.0	45	18.1
Black Bengal	India	1.3	12.7	31	14.0
Criollo	Venezuela	2.3	17.2	41	18.1
Damascus	Cyprus	3.5	21.6	50	10.8
Katjang	Malaysia	1.5	22.3	57	12.4
Malabar	India	1.8	14.3	34	12.2
Sudanese Desert	Sudan	1.7	20.8	52	21.8
West Af.Dwarf	Nigeria	1.4	12.9	32	12.2
Mean		2.1	18.0	44	15.7

[a]Single male kids [b]Weighted mean for multiple births

[c]Based on dressing percentage of 50%

Source: Devendra, 1985

TABLE 29. PROLIFICACY OF CRIOLLO GOATS UNDER EXTENSIVE PRODUCTION SYTEMS IN PERU[1]/

	Herd 1	Herd 2
No. kiddings	43	41
Total No. kids born	82	83
Singles, No.	14	8
Twins, No.	38	50
Triplets, No.	30	21
Quadruplets	-	4
% Singles	17.0	9.6
% Twins	46.3	60.2
% Triplets	36.7	25.3
% Quadruplets	-	4.9

[1]Data from farmers under dynamic survey. Feeding on range with no supplementation.

Source: Quijandría (1984)

TABLE 30. AVERAGE TOTAL MILK PRODUCTION AND OTHER RELATED TRAITS IN CRIOLLO GOATS UNDER SEMI-INTENSIVE PRODUCTION SYSTEMS

	No. Observations	Total Milk Production (kg)	Lactation Length (days)	Average Daily Production(kg)
Parturition 1	80	57.8± 3.5	146.7± 6.8	.38±.01
2	73	88.8± 6.3	177.2±10.7	.48±.01
3	65	150.1± 9.3	200.5± 9.0	.74±.03
4	51	155.2+10.0	184.5+ 9.5	.84+.03
Type of Parturition				
- Single	113	81.0± 5.8	159.0± 7.3	.47±.01
- Twin	142	122.9± 6.0	187.0± 6.2	.64±.02
- Triplets	14	154.7+18.5	185.1+20.3	.83+.08
GENERAL	269	107.0+ 4.3	175.2+ 4.7	.58+.01

Source: Quijandría (1984)

TABLE 31. LACTATION LENGTH, TOTAL AND DAILY MILK PRODUCTION BY BREED IN HONDURAS

Breed	Lactation Length (days)	Total Production (kg)	Average daily Production (kg)
Saanen	238	516.09	2.18
Nubian	183	335.18	1.81
Alpine	203	447.4	2.18
Toggenburg	205	436.4	2.13
Mean	207	433.77	2.09

Source: CATIE (1987)

TABLE 32. AVERAGE MAXIMUM AND MINIMUM DAILY MILK PRODUCTION BY BREED IN HONDURAS

Breed	Average daily production Max.	Min.
Saanen	2.95	0.727
Nubian	4.18	0.59
Alpine	4.81	0.545
Toggenburg	4.00	0.954

Source: CATIE (1987)

TABLE 33. HERITABILITY ESTIMATES FOR LITTER SIZE IN GOATS

Breed	Location	h^2	Reference
(1) Balady	Egypt	0.25	Tantawy and Ahmed (1960)
(2) Beetal	India	0.15[a]	Amble, et al. (1964)
(3) Black Bengal	India	0.09[a]	Moulick et al. (1966)
(4) Red Sokoto	Nigeria	0.08[a]	Adu, et al. (1979)
(5) Alpine	France	0.08[a]	Ricordeau et al. (1979)
(6) Damascus	Cyprus	0.01	Constantinou and Beuing (1983)

[a]At first kidding.

Source: Devendra (1985)

TABLE 34. REPEATABILITY AND HERITABILITY ESTIMATES OF MULTIPLE BIRTHS

Type of goat	Repeatability	Heritability	Reference
1. Egyptian Baladi	0.29	0.25	Tantaway and Ahmed(1960)
2. Beetal	0.22	0.15	Amble et al. (1964)
3. Black Bengal	0.15	0.09	Moulick et al. (1966)
4. Mubende	0.06	-	Sacker and Trail (1966a)
5. Kambing Katjang	0.08	-	
6. F_1 Anglo-Nubian x Kambing Katjang	0.14	-	Anuwar and Devendra (1970)
7. 3/4 Anglo-Nubian	0.20	-	

Source: Taneja (1982)

TABLE 35. HERITABILITIES FOR WEIGHT TRAITS

Age/Source	Ribeiro & Santos (1987)	de Souza et al.(1987)	Nagpal & Chawla(1987a)	Nagpal & Chawla(1987b)
Birth	.08	.30 $\pm$ .11	.24 $\pm$ .03	.27 $\pm$ .03
1 month	.04	-	-	-
2 months	.03	.17 $\pm$ .10	-	-
4 months	.08	.23 $\pm$ .11	-	.93 $\pm$ .12
6 months	-	.08 $\pm$ .10	.43 $\pm$ .10	.71 $\pm$ .10
9 months	-	-	.08 $\pm$ .17	.60 $\pm$ .14
Breed	Alpine x Nubian	SRD & Crosses	Beetal	Alpine x Beetal
Country	Brazil	Brazil	India	India

Source: Quijandría (1987)

TABLE 36. HERITABILITIES OF AND GENETIC AND PHENOTYPIC CORRELATIONS AMONG BODY WEIGHT AT DIFFERENT AGES.

		Weight at:		
Weight at:	**Birth (kg)**	**3 months (kg)**	**6 months (kg)**	**12 months (kg)**
Birth	0.041±0.005	-0.241±0.056	0.168±0.071	0.188±0.081
3 months	0.338±0.377	0.157±0.042	0.766±0.473	0.501±0.073
6 months	-0.164±0.366	0.574±0.296	0.229±0.053	0.484±0.077
12 months	-0.473+0.475	-0.718+0.348	-0.091+0.629	0.303+0.072

Diagonal values are pooled heritabilites, above the diagonal are phenotypic correlations and below the diagonal are genetic correlations.
Source: Acharya (1987)

TABLE 37. ESTIMATES OF HERITABILITIES AND GENETIC AND PHENOTYPIC CORRELATIONS AMONG FIRST LACTATION YIELD, FIRST LACTATION LENGHT, FIRST KIDDING INTERVAL, LIFE TIME PRODUCTION AND AGE OF FIRST KIDDING.

	X1	**X2**	**X3**	**X4**	**X5**
First lactation yield (X1)	0.320±0.065 (1412)	0.19±0.19	-0.89±0.66	0.67±0.14	-0.34±0.02
First lactation length (X2)	0.67±0.03 (1033)	0.04±0.05 (1036)	-0.50±0.18	-0.52±0.22	-0.35±0.03
First kidding interval (X3)	0.02±0.04 (728)	0.09±0.04 (728)	0.15±0.09	-0.40±0.10	0.67±0.10
Life time prod. (X4)	0.63±0.03 (429)	0.24±0.05 (429)	-0.03±0.05 (423)	0.30±0.14 (430)	0.38±0.17
Age at first kidding (X5)	0.14±0.03 (1033)	0.20±0.03 (1033)	0.07±0.03 (798)	0.01±0.05 (429)	0.54±0.12 (1236)

Diagonal values are pooled heritabilities, above the diagonal are phenotypic correlations and below the diagonal are genetic correlations.
Source: Acharya (1987)

TABLE 38. MEANS AND STANDARD ERRORS FOR THE FIRST 150-DAY MILK YIELD, TOTAL LACTATION YIELD & LACTATION LENGTH IN BEETAL AND ITS CROSSES WITH ALPINE AND SAANEN.

S.No.	Genotype	First lactation yield (in 150 days) (kg)	Total lactation yield (kg)	Lactation length (days)
1.	Beetal (B)	132.7 ± 7.1 (42)*	148.5 ± 8.2 (91)	196.5 ± 7.5 (91)
2.	Alpine (A)	213.0 ± 10.8 (27)	299.2 ± 29.3 (54)	253.7 ± 18.1 (54)
3.	Saanen (S)	187.4 ± 21.5 (12)	268.9 ± 25.2 (17)	258.7 ± 14.2 (17)
4.	A x B	199.8 ± 7.8 (55)	249.6 ± 8.6 (181)	239.3 ± 5.9 (181)
5.	S x B	244.9 ± 15.1 (24)	318.8 ± 22.1 (82)	267.6 ± 13.9 (82)
6.	A x B (3/4)	209.4 ± 10.4 (29)	-	-
7.	S x B (3/4)	242.2 ± 24.6 (10)	-	-

*Within parentheses are number of observations.

Source: Acharya (1987).

TABLE 39. MEANS AND STANDARD ERRORS OF LACTATION CHARACTERISTICS IN MALABARI & ITS CROSSES WITH ALPINE & SAANEN.

Sl.No.	Genotype	No. of observations	120 - day yield (kg)	Full lactation yield (kg)	Lactation length (days)
1.	Malabari	432	56.2±06.7	65.3±08.3	172.5±12.4
2.	AlpineXMalabari (F_1)	339	75.9±08.4	98.0±10.5	186.9±04.2
3.	AlpineXMalabari (F_2)	49	49.8±06.0	60.4±06.3	191.5±04.4
4.	AlpineXMalabari (3/4)	31	62.0±08.0	86.4±10.0	190.8±01.8
5.	SaanenXMalabari (F_1)	98	90.1±10.4	127.2±12.4	190.5±06.5
6.	SaanenXMalabari (F_2)	63	73.7±09.8	86.2±11.3	191.8±08.7
7.	SaanenXMalabari (F_3)	14	55.1±06.4	67.7±08.5	180.3±08.7
8.	SaanenXMalabari (3/4)	20	77.1±12.1	106.6±13.9	174.0±13.2
9.	AlpineX(SaanenX Malabari)	24	78.0±07.2	102.8±08.9	168.7±04.5
10.	SaanenX(AlpineX Malabari)	17	61.2±05.8	78.8±07.4	180.0±12.1

Source: Acharya (1987).

3.3 SWINE

3.3.1 Background

In temperate countries breeding practices over the last fifty years have directed selection and crossbreeding efforts to the improvement of feed conversion ratio, litter size, growth rate, carcass leaness and quality. The rapid progress in swine breeding has been accompanied by very successful research in housing, nutrition and sanitation. Commercial farms in developed countries use housing facilities designed according to latest knowledge, with automatic feeding devices and climate control. Animals are fed high density, high digestibility rations and sanitation control is so advanced that many herds obtain "Specific Pathogen Free" status.

In contrast, traditional swine production systems all over the world have changed very little over centuries. Swine are probably the most widespread small animal species present in mixed farming systems. Their prevalence on small farms in the tropics is illustrated by the results of a survey of 5 tropical Latin American countries. Of a total of 1582 pig farms, 73% were classified as small and contained less than 9 fattening pigs or 4 breeding sows (Paladines, 1988). Similarly, data from Chile showed that 51% of the national pig herd was to be found on farms with less than 10 head (Paladines, 1988).

When traditional swine production is the subject of improvement programmes, a divergence usually occurs between the technologies to be introduced and farmer objectives. This is related to the role of swine on small farms. They are commonly used as a source of savings and to utilize crop and family left-overs, residues and by-products that overwise have limited value *per se*. Lard production may also be of importance since it is a staple food in many regions of the world. Swine production is a zero or limited investment operation on the farm and it has remained so for many centuries. Farmers expect the pigs to feed themselves during part of their life cycle, either through grazing, scavenging or utilizing garbage. This orientation makes the task of selecting options for swine improvement with improved commercial technologies particularly difficult and knowledge derived from swine breeding in commercial operations is of very limited application.

The size of small, family swine herds is determined by the capacity of the system to feed the animal, so in many cases small litter size or high piglet mortality are a form of size control to keep animals in proper balance with feed resources. In these systems, the use of low quality feeds and the usual policy of marketing when the need for cash income arises, rather than when market weights are reached, limits the importance of breeds selected for rate of growth. Furthermore, the continuing demand of lard within the household favours animals that will accumulate fat instead of lean tissue.

It has been suggested that the intensive selection of improved breeds has led to substantial physiological differences compared with the criollo or native breeds of pig (Quijandría, 1979, unpublished data). These differences can be appreciated in the digestive tract length and volume, a fact which is probably accompanied by anatomical changes within intestine cell walls, length and size of the caecum and in microbial and bacterial presence in the digestive system. These findings have been partially ratified by nutritional studies in Central America in which protein requirements of criollo and improved pigs have been made (Gómez-Brennes et al. 1974a,b; 1975). Findings suggest that criollo pigs have a smaller protein requirement than improved pigs. No significant differences in growth have been obtained in criollo pigs with a limited supply of protein. Circulating serum proteins have normal levels in diets with low protein levels. The same studies also suggest that native pigs require the same aminoacid balance as improved animals. The main difference in protein utilization reflects the tendency of criollo pigs to accumulate more fatty tissue than improved breeds selected for lean meat production.

There have been no published studies defining clearly the nutritional requirements of criollo pigs and selection studies and crossbreeding schemes will have to take into account the physiological basis of their growth.

Traditional swine breeding systems have been described in Central and South America, Africa and Asia (CIAT, 1972; Eusebio et al, 1976; Fetuga et al, 1976; Goonewardena et al, 1984; Quijandría, 1979; Ventura, 1987; Wilkins and Martinez, 1983; and Cruz, 1983).

In Table 40 a description of the two most common systems of traditional pig raising in Central America is presented. The breeder is a producer of a small number of sows, devoted to the production of feeder pigs for sale or fattening on farm while the grower-fattener normally purchases 4 to 6 pigs to be raises to market ages, using crop residues. An extensive description of this system has been presented by Quijandría (1981).

In Table 41, the principal productive characteristics of swine under traditional and intensive production systems in Central America are presented. Looked at from a commercially oriented point of view, traditional farming systems are well below any of the productive standards of intensive systems, especially in feed conversion ratio. However, investments in housing, sanitation, labor and especially nutrition, are quite different in the two systems.

Productive comparisons have to be made taking into consideration the investment, management and nutritional conditions prevalent in the traditional farming systems. It is particularly important to consider that in small farming systems, swine play roles which are not necessarily market oriented, to the same extent as is true in commercial systems. Many efforts to try to improve traditional swine production systems have failed because they have not taken into consideration these social and anthropological factors, and have tried to introduce technologies which are not suited either economically or socially to the traditional family systems. One of these examples can be found in the final report of the Cacaotal Project in the Atlantic Coast of Colombia (CIAT, 1975). Closing the program, the report traditional indicates "the farmers' lack of knowledge of nutritional principles has caused them to refuse to buy protein supplements for their pigs". Swine are normally fed left-over products and cash investment, are limited. Furthermore, in a situation where small farmers themselves have a very low protein diet, it would be totally unrealistic to feed pigs rations with 16 to 18% protein levels.

In a more recent example, Brannon _et al_ (1983) compared test rations, developed by a Research Station, with the traditional ration used on small farms in Thailand. The results presented in Table 42 emphasize the differences in feed conversion ratio obtained at the research station, compared with the farms, and between the test and traditional ration. Economic analyses indicated that farmers were losing money using the improved ration and in their conclusions the authors indicated that "1) there undoubtedly exists a substantial technological gap between results under carefully control conditions existing in research stations and those at the level of the traditional farmers; 2) it appears that there is a wide range of managerial skills among small scale pig producers and that these skills may be quite important to the successful adoption of new technologies; 3) it has been hypothesized by some knowledgeable observers that pig production is a form of saving and 4) availability of local feedstuffs is undependable and shortages occur from time to time throughout the year" (Brannon _et al_, 1983). It can be appreciated that no analysis of the objectives of small-scale swine production, was made before starting the programme.

Low production and productivity are consistent characteristics of such systems and economic studies, using traditional economic tools, have shown this type of system to be wasteful and unprofitable due to high mortality rates, poor feed conversion, low reproductive rates and poor quality final products. These studies have shown substantial losses for the reproducer. However, in spite of these 'findings', small farmers still raise pigs and are apparently satisfied with the results. It is clear that pigs play an important socioeconomic role on small farms and the apparent contradiction between poor economic performance and the prevalence on swine on small farms appears to be due to inappropriate tools for economic analysis or a lack of social and anthropological understanding of the role of swine in small farming systems.

Results of a survey conducted in Central America (Quijandría, 1981), are presented in Table 43. Small farmers were satisfied with swine production in 87% of the cases, and 80% considered that it is a profitable operation. A total of 45% intended to improve sanitation, 25% to improve breeds and 25% to improve housing. However, only 5% intended to purchase food supplements and 35% to grow on-farm resources for the pigs.

As in other species, swine breeding requires a careful definition of goals and the economically important traits have to be identified for inclusion in selection and crossbreeding programmes. The information presented so far shows that accumulated knowledge and technologies from intensive commercial production systems can only be applied in those cases where traditional swine systems are evolving to semi-intensive operations with a commercial orientation. The definition of breeding practices in traditional farming systems will require an understanding of the socioeconomic factors affecting pig production.

In the next sections aspects of breed identification, environmental factors, genetic parameters and selection and crossbreeding results will be considered with emphasis mainly on traditional farming and semi-intensive commercial systems.

3.3.2 Identification of Most Productive Breed Groups

Over the last 40 years selected breeds from developed countries have been imported to tropical and subtropical areas, often replacing native animals and being incorporated into intensive commercial operations. In many cases, developing countries have depended exclusively on the importation of selected seedstock for their genetic progress due to lack of appropriate selection programmes.

Many of the improved breeds of swine ended up in small farmers' traditional systems. There is no evidence that these animals have survived as purebreds under the harsh environmental conditions of subsistence farming. However, in many regions of the world, crosses of imported breeds are now part of the germplasm of criollo or native animals.

The performance of exotic breeds has been directly related to the type of system into which they are introduced. Intensive operations in developing countries, with adequate housing, sanitation and nutritional practices have incorporated most of the best known breeds developed in Europe and North America. However as the system becomes semi-intensive, some breeds have faired better than others. Unfortunately, very few records have been kept on the fate of imported animals under semi-intensive or family production systems. It is fair to say that the most widespread breeds of swine of the developed world can perform well under intensive and certain semi-intensive conditions.

In view of the above mentioned facts, over the last 15 years interest has arisen in the evaluation of native breeds of pigs, especially under semi-intensive or family systems. The evaluation of local breeds has been made in Latin America, Asia and Africa (De Alba, 1972; Rigor and Kroeske, 1972; Gómez-Brennes et al, 1974a; Kleeman et al, 1975; Cabeza et al, 1976; Fetuga et al, 1976; Adebambo, 1982; Cheng, 1983 and 1984; Wilkins and Martinez, 1983; Goonewardena et al, 1984; Sutherland et al, 1985; Ventura, 1987). The results indicate that indigenous breeds are fairly well adapted to their environmental conditions, they also show an improvement in productive traits when subjected to "improved" management, housing and sanitation. Due to geographical restrictions common to native and local breeds, their relative importance is determined mainly by the particular ecological, environmental and socioeconomic conditions under which they are kept.

Table 44 presents means for productive characters of native pigs under a traditional swine-crops production systems in El Salvador, Central America. Even though litter size is adequate (8.1 to 7.3), weights at birth, 21 and 56 days are very low (.85, 2.53 and 6.53 kg respectively).

Under a programme promoting local native breeds in El Salvador, these animals were sampled and raised under "improved" conditions. In Table 45 the evolution of litter size, weights and mortality is presented for the period from 1977 to 1984. It can be appreciated that a combination of selection and improved environmental conditions can increase litter size at birth from 6.0 to 8.0 piglets. With regard to total litter weight at 56 days, a 100% increase was obtained from 23.9 to 50.5 kg in seven years. Even though there is no clear evidence of how much the improvement was due to genetic or environmental causes, in several reported cases, native breeds have tended to gain substantially in litter size and body weight once they are subjected to environmental improvements (Fetuga, 1976; Adebambo, 1982; Goonewardena et al, 1984; Ventura, 1987).

Since there is limited information on the performance of exotic breeds in family and semi-intensive systems, a rule of thumb for selecting exotic breeds to use in improvement programmes will be based on the election of those breeds long established in the country, and which are performing well under intensive management and easily available within the region.

3.3.3 Environmental Factors that Affect Productive Performance

The effect of environmental factors on production is directly related to the type of production system. Normally, large or commercially oriented swine operations minimize environmental effects and climatic variations through housing, management and sanitation measures. Through the use of balaced concentrated rations, the nutritional level is maintained very similar over time.

However, in semi-intensive and family raising systems, environmental effects tend to be fairly large. Two of the most important factors are nutrition, in terms of quality and quantity, and sanitation. Swine feeding is based on the yearly availability of feedstuffs; factors that affect crop yields will directly affect swine performance. Another important factor of external variation is the farmer himself. Surveys evaluating family production systems, have indicated that a wide variation in education knowledge and managerial skills in small farmers is present, and swine production results are a reflection of these variations (Brannon et al, 1983).

As in other domestic species, age of dam produces effects on litter and weight traits. However, small litter sizes and a depressed nutritional environment tend to obscure differences between different parities.

Finally, differences between specific regional systems are important sources of environmental variation for swine production. In tropical areas, cassava and tropical roots are the basis for swine feeding, while in others, bananas and plantains are the main source. In semi-tropical or semi-arid conditions, swine may be part of a corn-sorghum-swine system, in which pigs utilize left-overs and non-commercialized grains as feeds. In other systems swine are closely linked to small home cheese making operations for the use of whey. More complex systems common in Asia include crops, poultry, ducks, swine and fish in a very intensive type of family operation. These environmental differences will have to be taken into consideration in the choice of either native pig selection or crossbreeding programmes, because in each particular case production traits will have different economic values depending on the system.

3.3.4 Genetic Parameters of Productive Traits

A constant concern of commercially oriented swine producers in the developed countries has been the estimation of genetic parameters. According to genetic theory, populations under intensive selection schemes will show a trend towards smaller genetic variances, thus leading to changes in genetic parameters. Craft (1958) summarized the heritabilities of the most important productive traits in swine (Table 46). Because of the genetic structure of swine populations in developing countries, these early estimates are probably the most applicable. There have been no reported values of heritability estimates in native or local breeds (Pathiraja, 1987). Pooled estimates such as those presented by Craft (1958) can be useful guides in countries or regions that lack local information. Estimates from unselected native breeds, traditionally raised for specific productive abilities are not easily extrapolated to other breeds or regions of the world, because of the specific characteristics of the populations.

Two of the most importance factors limiting the estimation of genetic parameters are the small herd size on family farms and the lack of records. So attempts to estimate parameters are normally made at research stations, in which native animals are collected and raised. However, since they are normally kept under "improved" conditions, this could lead to estimates of limited usefulness for on-farm selection programmes.

With regard to genetic correlations, the same statements as for heritability are applicable and in the developed countries there is a substantial number of reports estimating genetic and phenotypic correlations (Craft, 1958; Fredeen, 1958).

3.3.5 Response to Genetic Improvement Programmes

a) Selection Results

It has been stated that early applications of population genetic improvement methods had led to a considerable increase in production and productivity in commercial swine operations in developed countries (Fredeen, 1958).

In developing countries, most efforts have been directed to the evaluation of the genetic potential of native breeds, under improved environmental conditions and to comparing them with exotic breeds (Fetuga, *et al*, 1976; Adebambo, 1982; Goonewardena *et al*, 1984; Ventura, 1987). Selection has been conducted mainly under research station conditions with introduced management and nutritional changes and there are no reported studies of on-farm selection of native pigs in traditional farming systems (Pathiraja, 1987).

Comparative evaluations have always shown the relatively poor performance of native animals, especially in traits related to feed conversion, growth and carcass quality. Since native pigs are raised for different economic purposes, these evaluations help very little in defining the real genetic potential of native breeds in their original environment, in which they were subjected to natural selection for many years.

There is a substantial need to initiate on-farm selection studies in traditional systems. Some recommendations have been proposed by Pathiraja (1987), but they have more value for semi-intensive operations or traditional systems normally oriented to market purposes. The first step in designing a selection program will be the clear characterizations of the role of swine within the whole system and of their particular environmental, management and nutritional conditions. Selection could be a long term attempt to improve production and productivity at the farm level, but because of its limitations it could be a costly operation.

b) Crossbreeding results

Throughout the world numerous studies have been published showing the advantages of crossbreeding exotic and native pigs. In Tables 47 and 48 the litter and weight performance of Zungo, a local Colombian breed, Duroc and crosses is presented. As expected, some improvements in litter size and weaning traits are obtained, due to heterosis, as well as adequate improvements in rate of gain and feed conversion. Recommendations on the use of crossbreeding for developing countries have been presented by Pathiraja (1986). However, these are mainly applicable to semi-intensive or market-oriented farming systems. In other areas evaluations of crossbreeding between exotic and native pigs have been reported (Kleeman *et al*, 1975; Adebambo, 1983) but their value and potential application are limited to areas in which they were carried out.

Crossbreeding has the advantage that short term improvement can be obtained, when the selection of breeds and sexes is appropriate. This holds true for litter survival and weight traits. Carcass characteristics are only partially improved by crossbreeding. In Table 49 the carcass characteristics of Zungo, Duroc and crosses are presented. The main differences observed are in backfat thickness, total fat, % lean parts and carcass length. As in selection studies, most of these evaluations have tried to compare native, exotic and crosses under research station conditions. The distribution of exotic breeds within small farms has not been recorded or studied in detail. However the genetic advantage of crossbreeding makes it an ideal tool for short term improvement of pigs.

In recommending crossbreeding schemes, careful consideration will have to be made of the social and environmental conditions in which pigs are raised. In many cases, pure breed animals would not survive the harsh environmental conditions (Pathiraja, 1986) and as a result crosses of native by improved breeds have to be introduced into the family systems, instead of pure-bred animals. Throughout the world, there are many improved breeds of pigs selected for particular productive conditions, and they could be selected to improve particular traits through crossbreeding in family systems. A careful initial evaluation must be made of the sources of improved animals, their quality and their cost in order that crossbred stock can be made easily available to family herds at appropriate prices from research stations or multiplier herds.

The formation of supplier herds of crossbred animals for small farm swine production improvement is an absolute necessity for a success of a crossbreeding programme.

TABLE 40. PRODUCTIVE CHARACTERISTICS OF SWINE TRADITIONAL PRODUCTION SYSTEMS IN CENTRAL AMERICA.

Traits	System: Breeder	Grower-Fattener
Population: (No.)		
Boar	1-2	-
Sows	2-5	-
Feeder pigs	8-16	4-6
Breeds: (%)		
Criollo	77	86
Crosses	20	12
Pure-breeds	3	2
Feed: (%)		
Produced on the farm	98	100
Purchased	2	-
Production:		
No farrowing/year (No.)	1	-
Pigs born alive (No.)	4-6	-
Mortality to weaning (%)	20-40	-
Mortality to final weight (%)	10-20	10-20
Age to final weight (months)	16-24	16-24
Final weight (kg)	60	60
Age to first mating (months)	16-20	-
Marketing: (%)		
Live sale	77	77
On farm slaughtered	33	33

Source: Quijandría (1981)

TABLE 41. PRODUCTIVITY OF SWINE UNDER TRADITIONAL AND INTENSIVE SYSTEMS IN CENTRAL AMERICA

Productive Traits	Production System Traditional	Production System Intensive
Number born	6	10
Mortality to weaning (%)	40	20
Litter size at weaning	2.5	8
Weaning weight (kg)	5	15
Age at slaughter (months)	18	6
Live weight at slaughter (kg)	60	90
Carcass yield (%)	65	77
Feed conversion ratio	15:1	4:1
Number of litter/year	1	2
Mortality (%)	10	3
Litter size at slaughter	2.2	7.7

Source: Quijandría (1981)

TABLE 42. COMPARISON OF PERFORMANCE OF PIGS ON NEROA1/ RATION AT RESEARCH STATION AND ON TEST RATION AND TRADITIONAL RATION AT FARM LEVEL*.

	NEROA ration at research station	**Test ration** at farm level**	**Traditional ration at farm level**
Initial weight (kg)	18.1	7.9	7.4
Final weight (kg)	90.0	97.2	86.4
Gain in weight (kg)	71.9	89.3	79.0
Daily gain (g)	642.0	366.0	305.0
Feed cost/kg of gain (B/.)	4.01	6.49	5.84
Average number days on feed	112.0	244.0	259.0
Total feed consumed (kg)	223.6	499.2	530.9
Conversion ratio	3.11	5.59	6.72

*Data refer to averages for the trial and are expressed in terms of a single pig.

**The test ration, though quite similar, was not identical to the NEROA ration and cost less per kg.

1/North East Regional Office of Agriculture.

Source: Brannon _et al_ (1983).

TABLE 43. SMALL FARMER ATTITUDES TOWARD SWINE PRODUCTION.

	% Of affirmative answers
Satisfied with swine production	87
Will expand	15
Profitable	80
Will improve breed	25
Will improve sanitation	45
Will improve housing	25
Will purchase food-supplements	5
Fair sale price	50
Will use credit	13
Will grow crops-pastures for feeding	35
Will use technical assistance	35

Source: Quijandría (1981).

TABLE 44. MEANS AND STANDARD ERRORS FOR PRODUCTIVE CHARACTERS OF NATIVE PIGS UNDER TRADITIONAL SWINE-CROPS PRODUCTION SYSTEMS IN EL SALVADOR1/

Productive Character	**Means**	**Standard Errors**
Days between farrowing	223.5	4.3
Farrowing/year, No.	1.6	0.03
No. born	8.1	0.31
No. 21 wk	7.5	0.19
No. 56 wk	7.3	0.17
Birth weight, kg	0.85	0.09
21 days weight, kg	2.53	0.07
56 days weight, kg	6.52	0.17
Daily gain birth, 56 days, g	101.55	2.75
Mortality birth, 56 days, %	9.9	--

1/ Results of a Dynamic Survey on 64 farms.

Source: Ventura (1987).

TABLE 45. EVOLUTION OF LITTER AND WEIGHT TRAITS OF CRIOLLO PIGS UNDER IMPROVED SYSTEMS IN EL SALVADOR.

Year	Litter Size		Total litter size		Mortality
	Birth	56 days	Birth	56 days	56 days
	No.		kg		%
1977	6.0	4.3	5.5	23.9	27.2
1978	7.7	4.9	6.3	33.5	36.1
1979	8.3	4.6	6.8	32.8	33.0
1980	8.1	5.5	6.7	40.0	28.8
1981	8.5	5.8	7.0	39.7	24.4
1982	8.2	6.4	7.1	44.7	17.2
1983	7.9	6.6	6.9	46.4	17.2
1984	8.0	6.7	7.3	50.5	16.4

Source: Ventura (1987)

TABLE 46. HERITABILITY OF ECONOMICALLY IMPORTANT TRAITS IN SWINE.

Trait	Heritability (%) Average	Range of observed values	Degree of heritability (arbitrary)
Performance traits			
Litter size at birth (No. of pigs)	15	0-24	low
Post weaning rate of wt gain	29	14-58	medium
Feed per unit of wt gain	31	8-72	medium
Litter size at weaning (No.of pigs)	12	0-32	low
Litter weight at weaning	17	3-37	low
Anatomical traits			
Length of body	59	40-81	high
Length of legs	65	51-75	high
No. of vertebrae	75	-	high
No. of nipples	15	-	low
Carcass traits			
Length	59	40-81	high
Loin eye area	48	16-79	high
Ham wt (percentage of carcass wt)	58	51-65	high
Shoulder wt (percent of carcass wt)	47	38-56	high
Fat cuts (percent of carcass wt)	63	52-69	high
Lean cuts (percent of carcass wt)	31	14-76	high

Source: Craft (1958).

TABLE 47. LITTER PERFORMANCE OF ZUNGO (Z) AND DUROC (D) SOWS.

Parameter	**Z x Z***	**D x Z**	**Z x D**	**D x D**
No. of Litters	7	4	3	4
Farrowing data				
No. of pigs/litter	8.6	9.0	9.0	9.0
Individual pig wt (kg)	0.96	1.08	1.22	1.31
Litter wt (kg)	8.2	9.8	11.0	11.8
Weaning data (56 days)				
No. of pigs/litter	5.9	6.8	6.0	5.5
Individual pig wt (kg)	10.53	13.10	13.56	13.15
Litter wt (kg)	61.7	88.4	81.3	72.3

*Parent designation: boar x sow

Source: CIAT (1975)

TABLE 48. PERFORMANCE OF ZUNGO, DUROC AND CROSSBRED PIGS DURING THE GROWING-FINISHING PERIDOS*.

Parameter	**Z x Z****	**D x Z**	**Z x D**	**D x D**
Duration (days)	182	131	128	126
No. of animals	16	19	14	12
Daily gain (kg)	0.44	0.61	0.61	0.63
Daily feed intake (kg)	1.93	2.42	2.38	2.44
Feed/gain	4.38	3.99	3.92	3.90

*Period from weaning to approximately 90 kg liveweight.

**Parent designation: boar x sow.

Source: CIAT (1975)

TABLE 49. CARCASS CHARACTERISTICS OF ZUNGO, DUROC AND CROSSBRED PIGS (SECOND LITTER).

Parameter	Z x Z*	D x Z	Z x D	D x D
Liveweight (kg)	90.1	91.5	91.1	91.8
Carcass yield (%)	83.0	82.8	84.2	82.6
Backfat thickness (cm)	5.2	4.7	4.6	4.1
Total fat (%)	32.3	30.4	28.5	26.0
Ham (%)	26.1	27.4	27.0	29.4
Lean parts (%)	33.6	37.0	37.3	41.8
Carcass length (cm)	88.4	91.3	92.8	90.2

*Parent designation: boar x sow.

Source: CIAT (1975).

3.4 GUINEA PIGS

3.4.1 Background

For many centuries guinea pigs have been an important source of animal protein to the inhabitants of the Andean Region (Colombia, Ecuador, Perú, Bolivia and Chile) of South America. However, this species has gained recognition as a domestic animal only in the last two decades, and it is in this period, that initial research efforts have been undertaken in several countries where its contribution to human diets is important. Hence information on guinea pigs as a domestic animal is still limited on several aspects of their life cycle and production characteristics. This is also true in the field of genetics even though research on this species yielded results that contributed to the foundation of population and physiological genetic theory (Quijandría, 1972). Since 1960, government institutions and universities in the Andean countries have started research programs designed to provide information on biological aspects of meat production by guinea pigs. Several publications have been made covering areas such as nutrition, reproduction, management and genetics (Aliaga, 1974; Quijandría, 1982; Chauca et al, 1984; Saravia et al, 1984).

Guinea pigs are raised mainly under a traditional family raising system with flock number between 5 and 40 animals per household, with an average of 12 animals. Raising takes place close to the kitchen, where animals are kept warm and use kitchen left overs as a source of food. Over the last 15 years a semi-intensive guinea pig production system has been started around several large cities of the Andean region. Flocks vary in size from 500 to 1000. They are normally market oriented using an infraestructure adequate for commercial production. The feeding is based on cut and carry forages, mainly alfalfa, with limited use of supplemental concentrates. Intensive commercial systems represent a new orientation in this species. Feeding is based on a combination of concentrates and green roughages with populations normally above 2,000 animals.

These three systems have different productive levels. While in the family system each dam produces an average of 5.5 offspring per year in the intensive commercial operations a dam can obtain 10 offspring per year. Also, weights and rates of growth show substantial differences between family raising and intensive commercial operations with market weights at around 13 weeks of 300 to 200 g in the former and 800 g to 1000 g in the latter.

3.4.2 Identification of most productive breed groups

The very recent interest in guinea pigs as domestic animals is clearly demonstrated by the lack of selection or utilization of improved breeds. Over the years several ecotypes of guinea pigs have been identified in Peru, Ecuador, Colombia and Bolivia. Some of them have shown different rates of growth and reproduction (Dillard *et al*, 1972). However, over 98% of guinea pig production is based on unselected, or unimproved native strains. In 1972, a selection experiment was started at the la Molina Research Station of the National Institute of Agricultural Research and Extension of Peru, and a very impressive set of results have been obtained. Some of these results will be dealt in the selection chapter in this text, however, in Table 50 a comparison of selected and unselected strains of animals in terms of productive performance is presented. The results show that the selected line produced 37-107% more, according to trait, than the unselected group.

Selected animals have been exported from Peru to Ecuador and Colombia, and data on the improvement of several traits will be presented in the crossbreeding section. The only selected and clearly identified improved strain is the one available at La Molina Research Station from INIPA. However, the multiplication capacity of the station is still limited, restricting the availability of these animals for a wide scale distribution program in the Andean countries.

3.4.3. Environmental Factors that Affect Productive Performance

As has been stated, levels of performance are obtained from comparing the three most common productive systems in guinea pigs. The most clearly identified factor affecting rate of gain and weight at market age is nutrition. The addition of concentrates improves the rate of growth. Another environmental factor identified as causing a large impact on productive traits is season of the year (Aliaga, 1974; Quijandría, 1982; INIPA, 1984). The summer season normally affects litter size and rate of growth in a negative way, while the winter season improves both litter and weight traits. In many cases, the effect of this factor is related to housing facilities, especially the location of the guinea pigs sheds with respect to the sunshine path and wind. In intensive commercial operations with adequate investment in housing facilities this factor can be minimized. Due to the short life cycle of the guinea pig, age of dam has some effect on litter size and weight. However, the rapid replacement of dams limits the degree to which this factor can, in practice, be manipulated.

With regard to reproductive performance, housing and management play a very important role. Inadequate housing and/or management practices tend to limit the genetic expression of litter size and litter performance, especially when they are related to animal density within pens. Management at mating time can have significant effects on reproductive performance. And there is a substantial difference between mating immediately after parturition, compared with mating after one or two cycles post partum (Chauca et al, 1984; Quijandría, 1987). Once again, environmental factors can be subjected to control in semi-intensive and intensive operations, through management and/or housing practices, minimizing the effects of external environmental factors.

3.4.4. Genetic Parameters of Productive Traits

Several studies have estimated heritabilities for weight and litter size traits, all of which have been conducted at La Molina Research Station-INIPA, Perú (Vaccaro et al, 1968; Dillard et al, 1972; Quijandría et al, 1983).

Two sets of parameter estimates have to be distinguished. Early estimates by Vaccaro et al, (1968) and Dillard et al, (1972) tend to be larger. Litter size for birth weight ranges from .15 to .58; weaning weight heritability estimates, range from .39 to .75 and 13-wk weight heritability estimates range from .38 to .58. Compared with other domestic animals these estimates are fairly high, however, since they were estimated from unselected synthetic populations, made up through the crossing of several ecotypes, a large amount of genetic variability is present. Estimates obtained after 5 generations of selection (Quijandría et al, 1983), obtained smaller heritability estimates ranging from .02 to .17 for birth, weaning and 13-wk weights heritabilities (Table 51).

The heritability estimates for litter traits obtained by Quijandría et al (1983), range from .06 and .30 for number born, number born alive and number weaned. These values are above those estimated for litter traits in other species.

Both, litter and weight traits heritabilities indicate that there is enough additive genetic variability present in guine pig populations to permit successful selection programmes.

Realized heritabilities estimated by Quijandría et al (1983) are presented in Table 53. Two methods were utilized, obtaining heritability estimates that range from .01 to .12 for litter size; .14 to .38 for 13-wk weight and -.01 to .04 for selection index heritability. These estimates were obtained after 4 generations of selection for litter size, 13-wk weight and a selection index combining both traits. These results are most closely related to those heritabilities estimated in other domestic species, and show that genetic progress can be obtained through selection.

Genetic and phenotypic correlations are presented in Table 54 and 55. As in other domestic species, associations between weights are normally high with values ranging between .24 to .86 for genetic correlations and .38 to .51 for phenotypic correlations. Surprisingly, there is a positive genetic and phenotypic correlations between 13-wk weight and a nomber born, born alive and number weaned. Apparently the negative effect on weight of a large litter size, influences only birth and weaning weights, and individual growth rates post-weaning, can overcome the negative effect of litter size, presenting a possitive association between litter traits and 13-wk weight. This could indicate that progress in litter size and 13-wk weight can be obtained simultaneously.

Research in guinea pig selection should yield additional information on genetic parameters. It is important to estimate genetic parameters under field conditions and obtain estimates of the genetic variability available for selection on local or native strains of guinea pigs.

3.4.5 Response to Genetic Improvement Programs

a) Selection Results

As has been indicated in the initial sections a long term programme of guinea pig selection was started in 1972. It continues to the present time, but analyzed and published information has dealt with only 5 generations of selection (Quijandría et al, 1983). The experiment started with foundation stock which originated from the combination of several populations from different areas of Peru collected by La Molina Research Station. They were maintained separately during an evaluation trial and later intercrossed. Information regarding the origin, performance and other aspects of the base population has been reported by Vaccaro et al, (1968) and Dillard et al, (1972).

Three selection lines and a control were initiated. Line 1 was mass selected for weight at 13 weeks of age; Line 2 for number born alive, and Line 3 selected for an index (I= 130 (litter size + 13-wk weight), derived from previous data from the same foundation stock (Dillard et al, 1972); the control was a randomly bred line. Selection was practiced at 13 weeks age in all lines, and random selection of sires and dams was practiced at this age in the control line. Selection was made without regard to parity, and no adjustment was made for parity or season of birth. Conditions in the selection experiment were similar to those found in semi-intensive and intensive commercial guinea pig operations.

Results of the first four generations of selection are shown in Table 56 and the realized heritabilities in Table 53.

Realized heritabilities for litter size are comparable to experimental ones reported for mice. This suggests the possibility of some small increments in litter size with selection, however, further generations of selection are needed to obtain more conclusive results. Selection for 13 wk-weight was effective in increasing this trait, and realized heritabilities were similar to those reported in mice and swine. These values were smaller than early estimates by Dillard et al (1972). Changes in the genetic composition of the population by selection could partially explain some of these differences, changes that are also reflected by differences in means and standard deviations for litter size and 13-wk weight. Index selection was not effective in increasing either litter size or 13-wk weight. These results show that weight can be improved by selection, with some suggestions that long-term selection may improve litter size. Further analyses on accumulated selection data will yield additional information on the effectiveness of selection.

b) Crossbreeding results

The utilization of the selected lines of guinea pigs from La Molina Research Station for crosses with native or unselected populations have yielded very interesting results. A selection of ecotypes from different regions from Peru and Colombia were maintained at the La Molina Research Station. All animals were subjected to the same management and nutritional practices. After one generation of adjusting the animals to the new environment, crosses between selected and unselected strains were conducted.

Results of crossbreeding trials are presented in Tables 57 and 58. Evidence from these crossbreeding trials, clearly indicates that rate of gain and weight at different ages can be increased through crossbreeding with selected lines.

Table 58 summarises results of a more extensive crossbreeding trial in which several local lines from Peru and Colombia were tested individually and crossed with selected animals from the La Molina Research Station. Results clearly indicate the genetic superiority of the La Molina selected line and an analysis of the average production traits from crossbred strains show that considerable improvement can be made by this means.

Crossbreeding experiments in traditional guinea pig raising systems have already been started but no information is yet available. It is important to initiate studies evaluating genotype by environment interactions in order to assess the relative merit of the La Molina selected strain under different nutritional and environmental conditions.

3.4.6 Conclusions

1. Genetics research on the guinea pig is of recent origin and presently available results justify continuing efforts in this field.

2. Selection has been successful in improving growth rate and, to a lesser extent, litter size.

3. More information is required on the genetic parameters of production traits of different populations under field conditions.

4. Research is also required to determine the importance of genotype: environment interactions, especially with reference to the comparative performance of the La Molina selected strain and its crosses under different environmental conditions in the field.

5. Crossbreeding between ecotypes and selected strains has been demonstrated to be effective in improving performance under the intensive environmental conditions of the La Molina research station. The work should be continued under field conditions in different parts of the Andean region.

TABLE 50. PRODUCTIVE TRAITS IN SELECTED AND UNSELECTED STRAINS OF GUINEA PIGS.

Productive Traits	Unselected	Selected
Litter size at birth	2.35	3.18
Birth weight, g	85.4	152.7
Weaning weight, g	257.5	418.6
13-wk weight, g	442.4	917.8

Source: Quijandría (1987)

TABLE 51. HERITABILITY ESTIMATES FOR WEIGHT TRAITS

Birth	Weaning	13 wk	References
.58 ± 1.10	.39 ± .08	--	Vaccaro *et al* 1968
.15 ± .12	.41 ± .15	.50 ± .15	Dillard *et al* 1972
.51 ± .26	.75 ± .31	.49 ± .23	Dillard *et al* 1972
.25 ± .11	.49 ± .13	.52 ± .13	Dillard *et al* 1972
.16 ± .07	.20 ± .08	.33 ± .08	Castro *et al** 1974
.24 ± .05	.07 ± .03	.58 ± .08	Chavez* (1979)
.02 ± .04	.10 ± .04	.17 ± .05	Quijandría *et al* 1983
.12 ± .03	-.13 ± .03	.12 ± .02	Quijandría *et al* 1983[1/]

[1/] Estimated by daughter-dam regression.

* Quoted by INIPA, 1984.

TABLE 52. HERITABILITY ESTIMATES FOR LITTER TRAITS

Trait	Daughter-dam regression analyses	From half-sib[a] analyses
Number born	.10 ± .02	.30 ± .30
No. born alive	.06 ± .02	.16 ± .31
No. weaned	.08 ± .02	.15 ± .31

[a] Litter trait estimates from maternal components.
Source: Quijandría _et al_, 1983.

TABLE 53. REALIZED HERITABILITIES AND STANDARD ERRORS.

Procedures	Litter Size	13 wk weight	Index
Method 1[a]			
A	.02 ± .15	.38 ± .11	-.23 ± .17
B	.01 ± .45	.27 ± .06	-.09 ± .13
Method 2[b]			
C	.05 ± .003	.26 ± .01	.04 ± .01
D	.07 ± .01	.18 ± .004	.04 ± .01
E	.12 + .21	.14 + .003	-.01 + .01

[a]A= Selection differentials unweighted for progeny number, adjusted for control selection differential; B= weighted and adjusted for control.
[b]C= Unweighted and unadjusted for control; D= weighted and unadjusted for control; E= weighted and adjusted for control.
Source: Quijandría _et al_, 1983.

TABLE 54. GENETIC[a] AND PHENOTYPIC[b] CORRELATIONS AMONG WEIGHTS AND AMONG LITTER TRAITS FROM SIB ANALYSIS.

Trait[c]	Birth weight	Weaning weight	13-wk weight
Birth weight		.51	.38
Weaning weight	.50 ± 2.33		.46
13-wk weight	.24 + .24	.61 + .16	
Trait[d]	**Number born**	**Number born alive**	**Number weaned**
Number born		.86	.67
Number born alive	.54 ± .44		.78
Number weaned	.75 + .40	1.27 + .51	

[a] Values below diagonal

[b] Values above diagonal

[c] From paternal half-sib analysis

[d] From maternal half-sib analysis

Source: Quijandría *et al* (1983)

TABLE 55. GENETIC[a] AND PHENOTYPIC[b] CORRELATIONS AMONG LITTER AND WEIGHT TRAITS FROM DAUGHTER-DAM REGRESSIONS.

	Number			Weight			
Trait	**Born**	**Born Alive**	**Weaned**	**Birth**	**Weaning**	**13-wk**	**Index**
No. born		.88	.66	-.29	-.32	.36	.44
No. born alive	.73		.78	-.38	-.45	.58	.58
No. weaned	.51	.77		-.42	-.46	.29	.49
Birth weight	-.97	-.89	-.63		.51	.39	.36
Weaning weight	-.87	-.79	-.61	1.20		.51	.46
13-wk weight	.39	.31	.33	.63	.83		.82
Index	.75	.78	.55	.54	.76	.92	

[a] Values below diagonal
[b] Values below diagonal
Source: Quijandría _et_ _al_ (1983)

TABLE 56. MEANS AND STANDARD DEVIATIONS BY LINE OF SELECTION (GENERATION 2).

Selection for:	**Litter Size (No.)**	**13-wk Weight (g)**	**Selection Index**
Litter size	3.27+1.2	866.9+131.7	1310.2+166.1
13-wk weight	2.83+1.0	919.3+127.5	1324.7+177.7
Index	2.90+1.17	874.4+127.3	1280.0+159.8
Control	2.92+1.2	830.4+117.4	1274.4+182.7

Source: Quijandría et al (1983)

TABLE 57. CROSSBREEDING EFFECTS OF SELECTED AND UNSELECTED LINES OF GUNIEA PIGS.

LINES	MEAN WEIGHTS (g) Birth	Weaning	8 weeks	13 weeks
Unselected				
Ecotype 2	87.42	263.57	356.70	458.90
Selected X Unselected				
Ecotype 2 X selected	104.45	297.30	427.70	539.50
Selected	150.66	405.50	634.56	829.62

Source: INIPA (1984).

TABLE 58. CROSSBREEDING RESULTS BETWEEN DIFFERENT STRAINS OF GUINEA PIGS.

		Weights (g)			
Crosses	**Origin**	**Birth**	**Weaning***	**8 weeks**	**12 weeks**
La Molina R.S. x La Molina R.S.	Coast Peru	148.4	458.9	860.8	1,091.3
Matucana x Matucana	Highlands Peru	87.4	263.9	356.7	458.9
Tacna x Tacna	Coast Peru	117.6	268.4	383.3	483.7
La Molina R.S. x Matucana	Highlands Peru	146.5	260.4	429.6	262.2
La Molina R.S. x Tacna	Coast Peru	123.6	393.4	582.6	795.4
La Molina R.S. x La Molina R.S.	Coast Peru	200.0	400.0	--	850.0
Pasto x Pasto	Highlands Colombia	80.0	200.0	--	330.0
La Molina R.S. x Pasto	Highlands Colombia	160.0	370.0	--	600.0

*Weaning at 4 weeks

Source: INIPA (1985).

3.5 SOUTH AMERICAN CAMELIDS

3.5.1 Background

South American Camelids are widely distributed all throughout the Andean countries. The most important llama population is in Bolivia and the most important alpaca population is located in Peru. The two species have been domesticated over centuries, while the vicuña and guanaco are still wild. It is estimated that 200,000 peasant families raise these animals as their main source of income. Alpacas and llamas produce fibres that are highly valued by the textile industry. Their meat is the main source of animal protein available to the inhabitants of the high Andes. In addition, hides and pelts are extremely important for handicrafts and are used in a number of products.

They have the advantage of being well adapted to the high Andes, and can use adequately low quality forages and perform at an altitude where no other domestic species produce satisfactorily.

In Table 59 the estimated population of these species in the Andean and other countries is presented.

Alpacas are raised primarily for fibre, and meat is a by-product. Llamas are raised for fibre, draught power and meat. There are three major production systems in the high Andes. The first one is practiced by large cooperatives or haciendas that raise large flocks of alpacas for commercial fibre production. Feeding is based on grazing of natural rangelands. Some improved pasture areas exist. Some inputs are used for health practices. Limited selection and breeding practices are used. It is common to Peru and Bolivia. The second system is practiced by pastoralists, who raise alpacas in the high Andes with very limited agricultural activity. Flocks are medium to large. Alpaca production constitutes their main source of income and subsistance. Within this system alpacas are raised together with sheep by these pastoralist societies. Feeding is based on natural rangeland grazing. Very limited inputs are used. Therefore, production and productivity are very low. The third system of alpaca and llama raising is a mixed agricultural-livestock system. Alpaca and llama herds are normally small. Very limited inputs are used and productivity is low. Animal production constitute a complementary income to crop production for small farmers. Draught power by llamas is normally used for the transportation of agricultural products.

Alpacas have been studied since the early 30's and especially over the last 20 years. A large set of information has been accumulated, especially in the area of reproductive physiology (Sumar, 1985). Recent studies have been concerned with the nutritional aspects and production systems research. Very limited information on alpaca breeding is available, which is surprising in view of the high actual and potential economic value of fiber production.

3.5.2 Identification of most productive breed groups

Two major breeds of alpaca have been identified: Suri and Huacaya; (Calle, 1979; Bustinza, 1985 and Sumar, 1985). Both breeds originated during the pre-Inca and Inca times. They have some different productive characteristics (Calle, 1982). However, neither of them can be clearly identified as superior for breeding programmes. Superior stock, which have been selected to some degree, are normally owned by SAIS, Cooperatives and Research Stations, while unselected animals are normally found in pastoralist and mixed systems. A substantial effort is needed to characterize alpaca production within several systems to provide basic information on their fibre and meat production abilities.

Only recently, studies on ecotypes of llamas have been started (Sumar, 1985). However, no published information is yet available.

3.5.3 Environmental Factors that Affect Productive Performance

No studies have been conducted to analyze the effect of environmental factors on fibre or meat production. However, it may be assumed that factors similar to those found in the case of sheep, like age of dam, parity and weight of dam will have marked effects over performance.

Nutritional supply, management and diseases are external factors with large influences over production and productivity (Calle, 1982; Sumar, 1985). Seasonal drought or heavy rainfall affect survival and growth rates of young alpacas. Also, seasonal variations in temperature during the season in which they are born can have substantial effects on their survival. However, limited information on these aspects is available (Espinoza, 1979; Rodriguez and Martinez, 1979a,b; Bustinza, 1985).

3.5.4 Genetic Parameters of Productive Traits

There is very limited information on the genetic parameters in alpacas, and none in llamas. Velasco et al, (1981) reported heritability estimates for body and fleece weights of .62 $\pm$ .2 and .35 $\pm$ .2, respectively. The genetic correlation between these two traits was -0.3. Roque *et al*, (1985) estimated heritabilities of .27 $\pm$ .08 for liveweight at two years of age, and .21 $\pm$ .07 for fibre staple length at the same age. Genetic correlations estimated between the weights of dams and those of offspring at birth and wearing were .32 and .36, respectively. The same authors estimated repeatibility values for birth and weaning weights of the order of .31 and .36, respectively.

Estimates are medium to large in size, indicating that selection can produce significant increases in body and fleece weight as well as in staple length. Since the genetic correlation is relatively small, improvement for these traits can be obtained almost simultaneously.

Velasco *et al*, (1981) reported some information on the inheritance of fibre color and quality. It is apparent that brown is dominant over black and apparently also over spotted patterns. Velasco et al (1981), also conclude that the Suri fibre characteristic (crimped) dominant over the Huacaya type (straight) and that single gene Mendelian inheritance is apparently involved.

The available information is still very limited for breeding programmes and there is a considerable need for further studies in alpaca and llama populations with regard to breed differences and genetic parameters.

3.5.5 Response to Genetic Improvement Programs

a) Selection Results

Although commercial alpaca enterprises practices have limited selection over the years, no information on their results is available. Three groups have initiated selection studies. One in the Central Sierra, supported by the Agrarian University and the Small Ruminant CRSP; the other in La Raya, Cuzco under IVITA sponsorship; and the third one at La Raya, Puno by the Universidad Nacional del Altiplano, Puno (Bustinza, et al, 1985). No results, have been reported yet and due to the long generation interval, additional time will be needed to obtain meaningful information

b) Crossbreeding results

There is no available information, since there are no clearly identified superior breeds. Velasco et al, (1981) studies crosses between the Suri and Huacaya, but only with the objective of studying the inheritance of fibre characteristics. Some grading-up efforts normally take place in peasant flocks through the acquisition of "improved" males from SAIS and Research Stations. Most of the phenotypic advantages are probably of environmental origin, such as high plane of nutrition and good sanitation. However, there is no evidence of any real genetic difference between "native animals" and "improved" ones.

Due to the economic importance of alpaca and llama production in the Andes, this species requires additional studies on the genetic characteristics of populations, selection and the potential of crossbreeding.

TABLE 59. ESTIMATED POPULATION OF SOUTH AMERICAN CAMELIDS (Thousands)

Country	Domestic		Wild	
	Llama	Alpaca	Vicuña	Guanaco
Peru	900	3290	65	5
Bolivia	2050	300	2	Few
Argentina	100	Few	10	500
Chile	85	0.5	10	17
Ecuador	2.5	Few	-	-
USA	3	-	-	-

Source: Sumar (1985)

3.6 CONCLUSIONS AND RECOMMENDATIONS

3.6.1 Farm Monitoring: Productive Data Under Small Farmer Conditions

As has been shown in the preceding sections, there is a lack of performance information on most of the small animal species, under small farmer conditions. Information on native and exotic breeds have been normally gathered under "improved conditions" in research stations. There is an urgent need to estimate productive parameters of native and exotic animals, as well as their crosses, under the environmental conditions in which the animals are raised. This involves the monitoring of productive data over a period time in and adequate number of samples.

At the same time, efforts must be made to obtain genetic parameters of production traits under small farm conditions. The lack of records on small farms makes this a very difficult task. The availability of personal computers, and the dynamic survey, applied under the farming system approach, can help gather productive information with adequate sampling techniques to permit conclusions to be drawn from the population under study.

It is particularly important to identify breed groups and crosses, in a way that the information can be stratified by systems, so that advantages of breed groups of crosses can be identified. The process of gathering information will also provide knowledge about the farming system, its interactions and the way that small animal species fit into it. Under these circumstances breeding plans can be designed more adequately.

3.6.2 Genetic Potential of Indigenous Breeds

The determination of the genetic advantages of local breeds is of particular importance in the definition of population genetic programmes. The first step is the establishment of the farm monitoring system, recommended in the preceding paragraph. This information, in combination with breed evaluation from research stations and knowledge of the relevant genetic parameters, will provide some of the answers required to define the strategic options involving crossbreeding and selection suggested by Cunningham, (1982).

Breed information is available, but it is incomplete in goats and hair sheep, and it is an absolute requirement in swine, wool sheep under small farmer conditions, guinea pigs and South American Camelids.

At the same time as indigenous breeds are evaluated, comparative information on exotic breeds and crosses can be collected with small additional efforts.

3.6.3 Economic Participation of Small Animals in Small Farmer Economy

The definition of economic goals is the first step in the organization of successful breeding programmes. Thus a clear understanding of the small animals' role in the whole farming system is of particular importance.

Socioeconomic studies, normally undertaken during the diagnostic phase of farming systems studies, should provide information on why and how animals are raised, on the nature of small farmers' expectations, and on the environmental restrictions under which the animals produce.

If such studies are carried out previous to the establishment of breeding programmes, it will be easier to fit appropriate genetic methodologies into the small farm system. This is particularly true with species as swine and wool sheep, in which improvement efforts have been oriented towards commercial operations, and there is an inadequate understanding of breeding requirements at the small farm level. Some information exists in the case of goats and hair sheep, but additional information is needed.

3.6.4 Methods of Disseminating Improved Stock to Small Farms

Once the breeding programme is ready for application, the principal requirement is the distribution of improved stock to target farmers.

The possible methods include: multiplier farms, artificial insemination and embryo transfer. Experiences, quoted in preceding sections, indicate that there are risks involved when providing selected, highly productive exotic breeds to small farms. This may be result in the death of the animal with the corresponding economic losses to the small farmer, who either had to pay cash or obtain credit to purchase the animal. Under these circumstances, it is important to define the delivery system by which the selected genes will be introduced into the population.

Of the three options available, embryo transfer is limited to research station conditions and could be useful only in the case of introduction of exotic breeds. Even though artificial insemination is used in swine, sheep and goats, its corrected application still presents severe restrictions on small farms. The correct detection of heat, poor roads and communications and the availability of equipment and materials (liquid nitrogen) in isolated places severely limit the possibilities of successfully using artificial insemination. Also, various experiences have shown very low fertility rates when artificial insemination has been used on small farms.

Options are limited to multiplier or nucleus herds. These could be research stations or commercial farms, located close to the target area whose purpose is to produce animals of an appropriate genotype for distribution to small farmers. An alternative to this system is the use of communal sires, managed by a selected small farmer. This will help reduce the cost of individual sires for single farms and provide a superior sire for use in small villages for several farmers.

Multiplier herds will have several uses, not only as a source of seedstock, but also to obtain valuable information on productive traits, performance and genetic parameters applicable to a target area. Nucleus or multiplier herds are required for all small animal species. In several countries, such herds of hair sheep and native goat herds are already available, they are very limited in the case of native swine, wool sheep, guinea pigs and the South American Camelids.

Priorities for animal breeding studies within the farming systems approach, are indicated in Table 60 for each species. The main areas of research include production data gathering, estimation of genetic parameters, definition of economic goals, selection, crossbreeding studies and the dissemination of improved stock. The Table aims at a very general evaluation and priorities might vary in specific countries or regions of the world. Nevertheles, it is considered that the priorities shown represent the main needs for work in the area of genetics in order to contribute fully to the improvement of the welfare of the small farmers in the tropics.

TABLE 60. PRIORITIES FOR BREEDING STUDIES WITH SMALL ANIMALS.

Studies	Swine	Sheep Hair	Sheep Wool	Goat	Guinea Pigs	South Am. Camelids
Farm monitoring (productive data gathering)	***	**	***	**	***	***
Breed & Crosses evaluation (native and exotic)	***	**	***	**	**	**
Estimation of genetic parameters (on-farm)	***	***	***	**	***	***
Definition of Economic Goals (Socioeconomic studies)	***	**	***	**	**	**
Selection (indigenous breeds)	**	***	**	***	***	***
Crossbreeding	***	*	**	**	*	*
Seedstock dissemination						
- Nucleus herd native	**	***	**	***	***	***
- Nucleus herd exotic	***	*	*	**1/	-	-
- Crossbred multiplier	***	*	**	**	-	-
- Artificial insemination	-	-	*	*	-	-

***, **, *: High medium and low priority, respectively.

- : Not available, not important

1/: Medium priority for milk production.

4. GENERAL POLICY FOR IDRC SUPPORT TO ANIMAL BREEDING STUDIES

4.1 Considering the Centre's objectives and type of beneficiaries, support for animal breeding studies *per se* should not be pursued. Rather, animal breeding studies should be supported when they are framed within a Farming Systems Research approach. This includes a clear definition of the target population, farmers' resources, management, goals and aspirations. Also an understanding of the production environment, the exogenous factors to the production system, and the strategies to disseminate the improved animals should be considered to justify the support.

Within this context, the type of studies to be supported would vary according to the general characteristics of the production system.

4.2 For subsistence farms, it is necessary to determine the full expression of the genetic potential of existing animals. Solid data are still scarce. Most probably, changing the existing animal base (e.g. by crossbreeding) will not merit support considering the limitation in the resources for improving the production environment and farmers' goals with respect to the animal component. Heavy subsidies would generally be needed to change this situation, in the case of large animals, to a degree where the use of new genotypes would be justifiable. In these cases, animal breeding efforts should to promoting the use of records and to including, within the general management programme, rational methods of culling the poorest performers and retaining breeding males from the best females.

An exception to this situation may be the case of guinea pigs and small ruminants, since the cost of the environmental changes required for improved (e.g. crossbred genotypes) are so much less. Local specific studies are recommended.

In general, breeding studies to respond to the various goals of farmers under these conditions are not justifiable due to their complexity and cost.

4.3 For subsistence - commercial farms, the fact that large increments in production can be obtained through crossbreeding show the potential for the introduction of improved animals. However, there is still limited evidence of quantifiable genetic - production environment relationships for the gradual improvement of production. In that respect location specific studies are also needed.

4.4 For commercial farms there is evidence of large improvements in production through the introduction of improved animals. Conclusions and recommendations with respect to studies for the different species throughout the text are applicable.

4.5 In general, the relations between the genetic and productive environment should be better quantified in biological and economic terms. For example, descriptors of the productive environment in nutritional terms (DM availability, Metabolizable Energy, Crude Protein) and their relation to the types of animals and their production potential should be known. This could be used in location specific studies to determine the economical potential for the improvement of the production system.

4.6 A large number of studies have been conducted throughout the tropical world in animal breeding. However, in most of them, there is a lack of appropriate measurements of important variables and therefore clear conclusion cannot be drawn. For example, in dual purpose cattle, measurements of milk and beef production, reproductive performance, calf performance, and description of the productive environment are needed. In many studies only some of those have been measured.

Therefore, an appropriate methodology for the description of performance under such conditions should be developed.

4.7 The strategy to use artificial insemination to disseminate improved germplasm should be carefully considered due to the logistical support and the technical expertise needed as well as inferior results as compared to natural service. The creation of nucleus herds could be a better alternative.

4.8 The use of embryo transfer for the improvement of the genetic base for small/medium farms in the tropics is not recommended due to its cost and limited impact.

5. REFERENCES

5.1 General

McDowell, R.E. and P.E. Hildebrant. 1980. Integrated crop and animal production: making the most of resources available to small farms in developing countries. A. Bellagio Conference. The Rockefeller Foundation. Working Papers.

FAO. 1986. Production Networks Food and Agricultural Organization.

Winrock International. 1978. The Role of Ruminants in Support of Man. Winrock International.

5.2 Cattle

Abubakar, B. 1985. Evaluation of the performance of Holsteins in Mexico and Colombia. Ph.D Thesis, Cornell University, Ithaca, N.Y. 79 p.

Abubakar, B., R.E. McDowell and L.D. Van Vleck. 1986. Genetic evaluation of Hosteins in Colombia. J. Dairy Science 69: 1081-1086.

Aluja, A. and R.E. McDowell. 1984. Decision making by livestock/crop small holders in the State of Veracruz, Mexico. Cornell International Agriculture Mimeograph No. 105. Cornell Univ., Ithaca, N.Y., 44 pp.

Alvarez, F. and G. Saucedo. 1982. Sistemas de doble propósito para los trópicos húmedos. In Vaccaro, L. (Ed.) Sistemas de Producción con Bovinos en el Tropico Americano. Instituto de Producción Animal, Facultad de Agronomía, UCV, Maracay. pp 113-135.

Aragon, A. and O. Deaton. 1981. Algunos aspectos genéticos y ambientales de un hato de doble proposito en Costa Rica. VIII Meeting, Asociación Latinoamericana de Producción Animal, Santo Domingo, Dominican Republic: G-30 (Abstract).

Bane, A. and C.A. Hultnas. 1974. La inseminación artificial del ganado vacuno en los paises en desarrollo. Revista mundial de Zootecnia 9: 6-1.

Bójorquez, C., L. Coronado, L. Vaccaro and D. Miles. 1978. Animal production sytems based on cultivated pastures in the Peruvian Sierra. IV World Congress of Animal Production. Buenos Aires (Abstract).

Breinholt, K. 1982. Producción de leche anual y comportamiento reproductivo en pequeñas fincas en el trópico boliviano. Producción Animal Tropical 7: 283-291.

Buvanendran, V. and P.H. Petersen. 1982. Genotype: environment interaction in milk production under Sri Lanka and Danish conditions. Acta Agricultura

Scandinavica 30: 369-372.

Camoens, J.K., R.E. McDowell, L.D. Van Vleck and J.D. Rivera Anaya. 1976a. Holsteins in Puerto Rico: 1. Influence of herd, year, age and season on performance. J. Agriculture, Univ. Puerto Rico 60: 526-539.

Camoens, J.K., R.E. McDowell, L.D. Van Vleck and J.D. Rivera Anaya. 1976b. Holsteins in Puerto Rico. III Components of variance associated with production traits and estimates of heritability. J. Agriculture Univ. Puerto Rico 60: 551-558.

Cardozo, R., E. Moreno, L. Vaccaro, R. Vaccaro, A. Hurtado, C. Peña, J. Vilorio and E. Romero. 1980. Proyecto de Desarrollo Lechero del Piedemonte del Edo. Barinas. Universidad Nacional Ezequiel Zamora, Venezuela. Vol. 1. 174 pp.

Chicco, C., D. Plasse and V. Bodisco. 1977. Reproducción de ganado bovino en Venezuela. In: Consulta de Expertos para el Mejoramiento de la Eficiencia Reproductiva del Ganado Vacuno en America Latina. FAO, Rome. pp 171-204.

Espinoza, J., R. Schellenberg, J. Gonzalez, A. Iglesias and J. Quiel. 1986. Estudio de sistemas de producción animal en Panamá (Proyecto Doble proposito IDIAP-CIID). III. Eficiencia reproductiva de 10 fincas en el área de Bugaba. X Meeting, Asociación Latinoamericana de Producción Animal, Acapulco, México: 59 (Abstract).

Everett, R.W. 1986. ET bulls don't measure up. Hoard's Dairyman, May 10, 1986: 511.

FAO. 1977. Consulta de Expertos para el Mejoramiento de la Eficiencia Reproductiva del Ganado Vacuno en America Latina. FAO, Rome. 213 pp.

FAO. 1979. Report, Expert Consultation on Dairy Breeding in the Humid Tropics. FAO, Rome. 46 pp.

Foote, R.H. 1981. The artificial insemination industry. In: Seidel, B.G. et al. (Eds.). New Technologies in Animal Breeding. Academic Press, New York. pp 13-39.

Fernândez Baca, S., R. de Lucia and L.C. Jara. 1986. Mexico: milk and beef production from tropical pastures - an experience in the humid tropics. World Animal Review 58: 2-12.

Filho, E.B. de O., 1973. Apreciacao preliminar da situacao da pecuaria leiteira em cinco localidades dos Estados de Sao Paulo e Minas Gerais. Arq. Esc. Vet. Univ. Minas Gerais 25: 157-168.

Gonzalez, C. 1980. Efecto de la producción de leche y amamantamiento sobre la actividad ovárica y comportamiento post-parto en bovinos tropicales. Notas Informativas. Grupo de Investigadores de la Reproducción Animal en la

Región Zuliana, Maracaibo, Venezuela.

Gonzalez, C. 1981. Factores que afectan la fertilidad al primer servicio en vacas mestizas. VIII Meeting, Asociación Latinoamericana de Producción Animal: F-21 (Abstract).

Hansen, L.B., A.E. Freeman and P.J. Berger. 1983. Association of heifer fertility with cow fertility and milk yield in dairy cattle. J. Dairy Science 66: 306-314.

Katpatal, B. 1977. El cruzamiento del bovino en la India. 2: Resultados del Proyecto Global para la India de Investigación Bovina Coordinada. Rev. Mundial Zootecnia 23: 2-9.

Kerala Livestock Development Board. 1985. Indo-Swiss Project Kerala for Livestock and Fodder Development. Kerala Livestock Development Board, Madras, India.

Kragelund, K., J. Hillel and D. Kalay. 1979. Genetic and phenotypic relationship between reproduction and milk production. J. Dairy Science 62: 468-474.

Lindstrom, U.B. 1976. El registro lechero en los paises en desarrollo. Revista Mundial de Zootecnia 19: 38-46.

Madalena. F. 1983. Conservation of genetic resources through commercial utilization. FAO/UNEP Joint Expert Panel Meeting on Animal Genetic Resources Conservation and Management. 24-27th October. Rome, Italy. Mimeo. 12 pp.

Madalena. F., R. da Silva Vemeque and R.L. Teodoro. 1985. Fatores que influenciam os precos do semen importado. Rev. Brasil. Genetica 8: 377-384.

McDowell, R.E. 1971. Feasibility of commercial dairying with cattle indigenous to the tropics. Cornell International Agriculture Development Bulletin No. 21., Cornell University, Ithaca, N.Y. 22 p.

McDowell, R.E., G.R. Wiggans, J.K. Camoens, L.D. Van Vleck and D. St. Louis. 1976. Sire comparisons for Holsteins in Mexico versus the United States and Canada. J. Dairy Science 68: 2418-2435.

Menéndez, A. and D. Guerra. 1981. Relación entre el valor genético de sementales Holstein evaluados en Cuba, Canadá y Mexico. VIII Meeting, Asociación Latinoamericana de Producción Animal, Santo Domingo, República Dominicana: G-38 (Abstract).

Moulick, S.K. 1978. Ranking of Jersey, Holstein and Brown Swiss bulls in India as compared with that of the United States and England as evidence of genotype: environment interaction. Indian J. Dairy Science 31: 330-337.

Nair, P.N.R. 1973. Evolutionary crossbreeding as a basis for cattle development in Kerala State (India). Thesis, Dr. Vet. Med. Zurich Univ., Switzerland. 116 pp.

Paladines, O. 1988. Analisis de la producción de ganado vacuno y leche, ganado porcino, cámelidos y cuyes en América Latina continental. In: Escobar, G. (Ed.). Latinoamerican Selected Commodities, CIID, Bogotá (in press).

Parekh, H.K.B. and A.B. Pande. 1982. Genetic evaluation of exotic sires under different environments and their accuracy. 2nd. World Congress on Genetics Applied to Livestock Production, Madrid. 7: 170-177.

Parekh, H.K.B. and J.P. Sahu. 1978. Studies on some economic traits of Tharparkar x Holstein half-bred females. Indian J. Animal Sciences 48: 853-858.

Patel, R.K., P. Kumar, T.P. Gangadharanm, J.P. Dhaka, K. Voegele, R. Suskumaran Nair and G. Sreekumaran Nair. 1976. Economics of crossbred cattle. National Dairy Institute Karnal: Indo-Swiss Project, Kerala, India. 161 pp.

Paterson, A.G., G.O. Garwin, W.J. Ehret, W. Avis and H.E. Twine. 1983. Artificial insemination versus natural breeding in a multi-breed beef herd under intensive management. South African J. Animal Science: 13: 257-261.

Planas, M.T. 1979. Study on the performance of different Holstein-zebu crosses in tropical conditions. Cuban J. Agric. Sci. 13:210 (Abstract).

Plasse, D. and O. Verde. Normas de evaluación genetica de animales reproductores: bovinos de carne en el trópico de América Latina. Asociación Latinoamericana de Producción Animal (in press).

Powell, R.L. and F. Dickinson. 1977. Progeny tests of sires in the United States and Mexico. J. Dairy Science 60: 1768-1772.

Prada, N. 1978. Programa de selección por inseminación artificial para leche y carne en Cuba. FAO/SIDA Seminario sobre Mejoramiento Genético e Inseminación Artificial, La Habana, Cuba, 19 pp (Mimeo).

Prada, N. 1979. Programa de cruzamiento lechero en Cuba. Seminario sobre Cruzamiento de Bovinos de Leche en el Trópico. VII Meeting, ALPA, Panamá, 11 pp. (Mimeo).

Preston, T.R. 1976. Prospects for the intensification of cattle production in developing countries. In: Smith, A.J. (Ed.) Beef Cattle Production in Developing Countries. Edinburgh Univ. Press, Scotland. pp 242-257.

Schellenberg, R. 1983. Untersuchungen zur Milch- und Fleischerzeugung in Rinderbestanden Landwirtschaftlicher Betriebe des Tropischen Tieflandes Nordkolumbiens. Dr. Agr. Thesis, Technische Universitat Berlin. 207 pp.

Schneeberger, C.P., K.E. Wellington and R.E. McDowell. 1982. Performance of

Jamaica. Hope cattle in commercial dairy herds in Jamaica. J. Dairy Science 65: 1364-1371.

Seré, C. and L. Rivas. 1987. The advantages and disadvantages of promoting expanded dairy production in dual purpose herds: evidence from Latin America. In: Trends in CIAT Commodities, CIAT, Cali, Colombia pp 34-56.

Seré, C.,R. Schellenberg and D. Estrada. 1982. Ganadería de doble propósito diagnostico de sistemas de las provincias centrales. Panama: Información preliminar. Estudio Comparativo, Banco Nacional de Panamá y Centro Internacional de Agricultura Tropical, Cali, Colombia.

Seré, C. and L. Vaccaro. 1985. Milk production from dual-purpose systems in tropical Latin America. In: Smith, A.J. (Ed.) Milk Production in Developing Countries. Edinburgh Univ. Press, Scotland. pp 459-475.

Silva, G., N. Martinez and O. Verde. 1981. Factores que afectan la producción en vacas lecheras de la zona alta de Venezuela. VIII Meeting, Asociación Latinoamericana de Producción Animal, Santo Domingo, Dominican Republic: G-32 (Abstract).

Silva, G. and O. Verde. 1983a. Comportamiento productivo de seis grupos raciales en la zona alta de los andes venezolanos. IX Meeting, Asociación Latinoamericana de Producción Animal, Santiago, Chile: GM-27 (Abstract).

Silva, G. and O. Verde. 1983b. Comportamiento reproductivo de siete grupos raciales de bovinos en la zona alta de Venezuela. IX Meeting, Asociación Latinoamericana de Producción Animal, Santiago, Chile: GM-39 (Abstract).

Syrstad, O. 1985. Relative merits of various *Bos taurus* dairy breeds for crossbreeding with *Bos indicus* cattle. Livestock Production Science 12: 299-307.

Vaccaro, L. 1984. El comportamiento de la raza Holstein Friesian comparada con la Pardo Suiza en cruzamiento con razas nativas en el trópico: una revisión de la literatura. Producción Animal Tropical 9: 93-101.

Vaccaro, L. 1986. Sistemas de producción bovina predominantes en el trópico latinoamericano. International Seminar: Sistemas de Producción Doble Proposito en el Trópico , Bogotá, Colombia, Sept. 17-19, 1986. Mimeo 17 pp.

Vaccaro, L. 1987a. Aspectos del mejoramiento genético de bovinos de leche y de doble proposito. Boletín Técnico No. 1, Instituto de Producción Animal, Facultad de Agronomía, Universidad Central de Venezuela, Maracay. 44 pp.

Vaccaro, L. 1987b. Investigaciones realizadas en el área de genética de bovinos de leche en el Instituto de Producción Animal, Facultad de Agronomía, UCV. Annual Report 1985/6, Instituto de Producción Animal, Facultad de Agronomía, Universidad Central de Venezuela, Maracay, Venezuela. pp 159-178.

Vaccaro, L. and R. Vaccaro. 1981. Perdidas hasta el primer parto en hembras Pardo Suizo x Holstein Friesian x cebú en un sistema intensivo de producción de leche en el trópico. Producción Animal Tropical 6: 337-347.

Vaccaro, L., R. Vaccaro and R. Cardozo. 1980. Factores que afectan la performance de vacunos de leche en rebaños comerciales del Estado Barinas. II Congreso Venezolano de Zootecnía, Guanare, Venezuela: 83-84 (Abstract).

Vaccaro, L., R. Vaccaro, R. Cardozo and M.A. Benezra. 1983. Supervivencia de hembras Holstein y Frisonas importadas y de su progenie nacida en Venezuela. Producción Animal Tropical 8: 97-102.

Vaccaro, L., R. Vaccaro, N. Márquez and P. Argenti. 1986a. Control de producción en rebaños de doble propósito en Venezuela. 2. Evaluación genética de las vacas. X Meeting Asociación Latinoamericana de Producción Animal, Acapulco, México: 115 (Abstract).

Vaccaro, R., A. Pallete and A. Flores. 1979. Producción y tipo en toros de semen importado. VII Meeting, Asociación Latinoamericana de Producción Animal, Panama: G-14 (Abstract).

Vaccaro, R., L. Vaccaro, N. Márquez and P. Argenti. 1986b. Control de producción en rebaños de doble propósito en Venezuela. 1. Producción lechera y peso del becerro. X Meeting, Asociación Latinoamericana de Producción Animal, Acapulco, Mexico: 99 (Abstract).

Valle, A. 1981. Heredabilidad de caracteristicas productivas y reproductivas en vacas tipo Carora. VIII Meeting, Asociación Latinoamericana de Producción Animal, Santo Domingo, Dominican Republic: G-26 (Abstract).

Van Vleck, L.D. 1977. Theoretical and actual genetic progress in dairy cattle. Proc. Internacional Conference on Quantitative Genetics. Iowa State Univ. Press. pp 543-567.

Van Vleck, L.D. 1981. Potential Genetic impact of artificial insemination, sex selection, embryo transfer, cloning and selfing in dairy cattle. In: Seidel, B.G. et al. (Eds). New Technologies in Animal Breeding. Academic Press, New York. pp 221-242.

Wilkins, J.V., J.A. Alí and C. Vaca Diez. 1979. El cruzamiento para la producción de leche en los llanos bolivianos. VII Meeting, Asociación Latinoamericana de Producción Animal, Panamá. Mimeo 7 pp.

5.3 Sheep

Alderson, Anne, A. Naranjo, D.D. Kress, P.J. Burfening, R.L. Blackwell and G.E. Bradford. 1982. Sheep: Comparison of Rambouillet, Corriedale, American Romney Marsh, British Romney Marsh with Native Criollo y Colombia. Goat and Sheep Res. 2:38-49.

Alvarez Calderon, R. 1965. El nuevo tipo de ovinos Junin: La futura raza del Perú. Cerro de Pasco Corporation-División de Ganadería.

Blackwell, R.L. 1983. Objetivos y Políticas del Mejoramiento Genético en Ovinos. VII Congreso Nacional de Ciencias Veterinarias. ICA, Perú.

Burfening, P.J., M. Carpio, D.D. Kress and R.L. Blackwell. 1981. Reproductive Performance of Improved Sheep in the Central Highlands of Perú. J. Anim. Sci. 54: 177 (Abstract).

Cabrera, P., G. Huapaya, M. Carpio, R. Blackwell and B. Quijandría. 1982. Parametros Genéticos y Fenotípicos para Peso Corporal y de Vellon y Longitud de Mecha en Ovinos Corriedale y Junín x Corriedale. Resúmenes V Reunión Científica Anual Asoc. Peruana de Producción Animal. Cajamarca, Perú.

Cheng, P. 1984. Sheep breeds of China. World Animal Review. 49: 19-24.

Diez, et al, 1973.

Fitzhugh, H.A. and G.E. Bradford (Editors). 1983. Hair sheep of Western Africa and the Americas: A genetic resource for the tropics. A Winrock International Study published by West View Press.

Gonzalez-Stagnaro, C. 1985. Crianza y Producción de las Ovejas Tropicales. Mesa Redonda de Coordinación y Apoyo a los Programas Ovinos en los Países de la Zona Andina. Oficina Regional FAO, Quito, Ecuador.

Gonzalez-Stagnaro, C. 1979. Eficiencia Reproductiva y Productiva de Ovejas West African en Explotaciones Comerciales Semi-intensivas en una zona semi-arida de Venezuela. Universidad del Zulia, Instituto de Investigaciones Agronómicas. Facultad de Agronomía.

Huapaya, Gladys. 1985. Estimación de Parámetros Genéticos y Fenotípicos para peso vivo, Peso de vellón, Longitud de Mecha en ovinos Junín, Corriedale y Progenie Junín x Corriedale. Tesis Magister Scientia. Universidad Nacional Agraría.

Land, R.B. and D.W. Robinson (Editors). 1985. Genetics of Reproduction in Sheep. Butterworth, London.

Lencinas, Maria, R. Alencastre, B. Quijandría and R. Blackwell. 1984. Reporte Preliminar sobre Parámetros Biológicos en Ovinos Criollos. Resúmenes VII Reunión Científica Asociación Peruana de Producción Animal. Lima, Perú.

Mason, I.L. (Editor). 1980. Ovinos prolíficos tropicales. Estudio FAO de Producción y Sanidad Animal. No. 17.

Maule, J.P. 1977. Barbados Black Belly Sheep. World Animal Review. 24: 19-23.

Montesinos, M. Eugenia. 1983. Selección de Carneros Corriedale Mediante la aplicación de Pruebas de Performance y Progenie en el Centro Experimental Chuquimbabilla. Tesis Médico Veterinatio-Zootecnista. Universidad Nacional del Altiplano.

Montesinos, E., M. Lencinas, R. Alencastre, B. Quijandría and R. Blackwell. 1985. Selección de Carneros Corriedale por Performance y Progenie en el Centro Experimental de Chuquibambilla. Resúmenes VII Reunión Científica Asociación Peruana de Producción Animal. Lima, Perú.

Turner, Helen Newton. 1956. Measurement as an aid to selection in breeding sheep for wool production. A.B.A. 24: 87-118.

Villarroel, J. and M. Gamarra. 1978. El Ovino Raza Junín. SAIS "Tupac Amaru" Limitada No. 1. Pachacayo, Perú.

Young, L.D., G.E. Dickerson and N.M. Fogarty. 1985. Evaluation and utilization of Finn sheep. In "Genetics in Reproduction in Sheep". R.B. Land and D.W. Robinson, Editors. Butterworth, London.

5.4 Goats

Acharya, R.M. 1987. Breed of Goats and Research Programmes for their Improvement in India. Proc. IV International Conference on Goats. Brasil.

Angwenyi, G.N. and T.C. Cartwright. 1987. Effect of crossbreeding East African, Galla and Boer goats on body size growth rate and kid survivability in Kenya. Proc. IV International Conference on Goats. Brasil (Abstract).

Ashmawi, G.M. 1982. Milk production and growth rate in the Baladi goat. Proc. III International Conference on Goat Production and Disease. Arizona, U. S. A. (Abstract).

Bhatnagar, D.S., D.S. Chawla and R.C. Sharma. 1982. The effect of crossbreeding on milk production in dairy goats. Proc. III International Conference on Goat Production and Disease. Arizona, U. S. A. (Abstract).

CATIE. 1987. Situación de la Producción Caprina en Centro América y República Dominicana. Centro Agronómico Tropical de Investigación y Enseñanza. Costa Rica.

Chawla, D.S. and D.S. Bhatnagar. 1982. Reproductive performance of dairy goats. Proc. III International Conference on Goat Production and Disease. Arizona, U. S. A. (Abstract),

Chawla, D.S. and S. Nagpal. 1982. Role of exotic genes on growth rate of Beetal crosses. Proc. III International Conference on Goat Production and Disease. Arizona, U.S.A. (Abstract).

Constantinou, A. and A.P. Mavrogenis. 1987. Genetic and phenotypic relationships among body weight, milk yield and litter size in adult Damascus goat. Proc. IV International Conference on Goats. Brasil (Abstract).

Devendra, C. 1985. Prolific breeds of goats. In "Genetics of reproduction in sheep". Land and Robinson, Editors. butterworth, London.

Devendra, C. 1981. Meat production from goats in developing countries. British Society of Animal Production. Occasional publication No. 4.

de Souza, F.J., J.J. Ferreira de Miranda, F.H.F. Machado and A.A.O. Fernández. 1987. Heritability estimates of phenotypic genetic and environmental correlations at different ages of goats in Central Sertao Zone of Ceara State. Proc. IV International Conference on Goats. Brasil (Abstract).

de Souza, J. and G. Baker. 1987. Brazilian goats: Production level, production systems and production potential and strategies. Proc. IV International Conference on Goats. Brasil.

Figueiredo, E.A.P., A.A. Simplicio and K.P. Pant. 1982. Evaluation of goat breeds in the tropical north east Brasil: A study of birth related traits of native and exotic goat breeds. Proc. III International Conference on Goat Production and Disease. Arizona, U. S. A. (Abstract).

French, M.H. 1970. Observations on the goat. FAO Agricultural Studies. No. 80.

Gonzalez, C. (Editor). 1979. Producción Caprina en Medios Dificiles de América Látina. VII Reunión Latinoamericana de Producción Animal. Panama.

Khan, B.U. and K.L. Sahni. 1982. Evaluation of certain non genetic factors as a source of variation in growth performance and milk yield in Jamnapari goat under semi-arid farm conditions. Proc. III International Conference on Goat Production and Disease. Arizona, U. S. A. (Abstract).

Mason, I.L. and V. Buvanendran. 1982. Breeding plans for ruminant livestock in the tropics. FAO Animal Production and Health Paper. No. 34.

Mecha, I. and C.C. Agunwanba. 1982. Classification of goats in southern Nigeria: West African Dwarf Goats. Proc. III International Conference on Goat Production and Disease. Arizona, U. S. A. (Abstract).

Meza Herrera, C., F. Sanchez and G. Torres-Hernandez. 1987. Genetic and environmental factors affecting preweaning traits in goats. II. Variance components and heritability of birth weight. Proc. IV International Conference on Goats. Brasil. (Abstract).

Meza Herrera, C., F. Sanchez and G. Torres-Hernandez. 1987. Genetic and environmental factors affecting preweaning traits in goats. III. Variance components and heritability of one month weight and average daily gain. Proc. IV International Conference on Goats. Brasil. (Abstract).

Meza Herrera, C., F. Sanchez and G. Torres-Hernandez. 1987. Genetic and environmental factors affecting preweaning traits in goats. I Breed and Environmental Factors Affecting Birth Weights, one month weight and average daily gain. Proc. IV International Conference on Goats. Brasil (Abstract).

Mittal, J.P. 1987. Sekhawati: A promising goat breed from India arid zone. Proc. IV International Conference on Goats. Brasil. (Abstract).

Mukherje, T.K., J.K. Peters, T. Banumathi, G. Diechert and P. Hordst. 1982. Crossbreeding as a tool for overcoming the antagonism between fecundity and weaning ability with goats under tropical conditions. Proc. III International Conference on Goat Production and Disease. Arizona, U. S. A. (Abstract).

Nagpal, S. and D.S. Chawla. 1987. Estimates of Genetic Parameters of Body Weight of Alpine x Beetal Goat. Proc. IV International Conference on Goats. Brasil. (Abstract).

Nagpal, S. and D.S. Chawla. 1987. Genetic estimates on body weights of Beetal Goats. Proc. IV International Conference on Goats: Brasil (Abstract).

Patil, V.K. and U.Y. Bhoite. 1987. Effect of Source of Angora on Growth, Reproduction and Mohair Traits. Proc. IV International Conference on Goats. Brasil (Abstract).

Patil, V.K. and D.P. Koratkar. 1987. Crossbreeding a local goat with angora to evolve an indian mohair breed. Proc. IV International Conference on Goats. Brasil. (Abstract).

Quijandría, B. 1984. Goat Research Project in Northern Peru. In "Partners in Research". R.D. Blond, Editor. A five year report of the Small Ruminant Collaboration Support Program. University of California. Davis.

Quijandría, B., M. Callacna, M. Garcia and T. Schlosser. 1982. Milk Production in Criollo Goats in the Coastal Area of Peru. J. Anim. Sci. 57:134.

Rana, Z.S., S.C. Chopra and D.S. Balaine. 1982. Comparative performance on Beetal goats and its crosses with French Alpine and Anglonubian. Proc. III International Conference on Goat Production and Disease. Arizona, U. S. A. (Abstract).

Rattner, D. 1987. A comparison of three east mediterranean goat breeds. Proc. IV International Conference on Goats. Brasil. (Abstract).

Ribeiro and Santos. 1987.

Sahni, K.L. and D.S. Chawla. 1982. Crossbreeding of dairy goats for milk production. Proc. III International Conference on Goat Production and Disease. Arizona, U. S. A.

Singh, R.N. and A.K. Basuthakur. 1982. A production study on goat populationsof India. Proc. III International Conference on Goat Production and Disease. Arizona, U.S.A. (Abstract).

Singh, R.N. and R.N. Acharya. 1982. Improvement through selection for milk in a closed flock of Beetal goats. Proc. III International Conference of Goat Production and Disease. Arizona, U. S. A. (Abstract).

Souza, W.H., A. Rodriguez, E.A.P., Figueiredo, P.R.M. Leite and K.P. Pant. 1987. Prewening growth of German Alpine, Anglonubian and SRD kids under semi-intensive grazing. Proc. IV. Conference on Goats. Brasil. (Abstract).

Steibach, J. 1987. Evaluation of indigenous and exotic breeds and their process for production in unfavorable environments. Proc. IV International Conference on Goats. Brasil.

Taneja, G.C. 1982. Breeding goats for meat production. Proc. III International Conference on Goat Production and Disease. Arizona, U.S.A.

Wahid, A, M. Jemalos and A. Shukri. 1987. Growth performance of Katjang, Saanen x Katjang and Anglonubian x Katjang goats. Proc. IV Conference on Goats. Brasil (Abstract).

Wilson, R.T. 1982. Productivity of indigenous goats in the traditional livestock system of semi-arid Africa. Proc. III International Conference on Goat Production and Disease. Arizona, U. S. A. (Abstract).

5.5 Swine

Adebambo, O.A. 1982. Evaluation of the genetic potential of Nigerian indigenous pigs. En: Proc. 2nd Wld Cong. Genetic Appl. Livestock Prod., Madrid, p. 543-553.

Adebambo, O.A. 1983. Crossbreeding Nigerian Indigenous pigs: effect of crossing on performance characteristics. En: Proc. 5th Wld Conf. Anim. Prod., Tokyo, 14-19 Agosto, 1982, p. 76 (Extracto).

Brannon, R.H., C. Sirirugsa and B.T. Dean. 1983. Testing of research station results at the farm level: lessons from a pig feeding trial in north east Thailand. Trop. Sci. 21: 75-84.

Cabeza, M., J. Buitrago, A. Owen and M.F. Guerrero. 1976. Un estudio del cerdo nativo (Zungo pelado) de Colombia. Univ. Nac. ICA. Publ. s/n.

Cabeza, M., J. Buitrago and A. Owen. 1977. Rendimiento y comportamiento de cerdos criollos Zungo vs Duroc-Jersey. VI Reunión ALPA. La Habana, Cuba.

CIAT. 1972. Sistemas de Producción de Porcinos en América Latina. Centro Internacional de Agricultura Tropical. Seminario Setiembre 18-21, 1972. Cali, Colombia.

CIAT. 1974. Informe Anual. Centro Internacional de Agricultura Tropical. Cali, Colombia.

CIAT. 1974. Informe Anual. Centro Internacional de Agricultura Tropical. Cali, Colombia.

Craft, W.A. 1958. Fifty Years of Progress in Swine Breeding. J. Anim. Sci. 17: 960-980.

Cruz, E.N.M. 1983. Potential of integrated farming system in Asia with particular emphasis on the use of the fresh manure from pigs, chickens and goats for fish ponds. En: Proc. 5th Wld Conf. Anim. Proc., Tokyo, 14-19 Agosto 1982, Vol. 1, p. 282-293.

Cheng, Pei-Lieu. 1983. A highly prolific pig breed of China-the Taihu pig. Parts 1 and 2. Pig News Inf., 4 (4): 407-425.

Cheng, Pei-Lieu. 1984. A highly prolific pig breed of China-the Taihu pig. Parts 3 and 4. Pig News Inf., 5(1): 13-18.

De Alba, J. 1972. Productividad de razas indigenas y exóticas de ganado porcino en America Latina. Revista Mundial de Zootecnia, 4: 25-28.

Eusebio, J.A., B.I. Rabino and E.C. Eusebio. 1976. Recycling system in integrated plant and animal farming. Natl. Sci. Develop. Board-Univ. Philipp. Tech. Bull No. 2.

Fetuga, B.L., G.M. Babatunde and V.A. Oyenuga. 1976. Performance of the indigenous pig of Nigeria under intensive management conditions. Niger J. Anim. Prod. 3: 148-161.

Fredeen, H.J. 1958. Selection and Swine Improvement. A.B.A. 26: 229-241.

Gomez-Brenes, R.A., R. Jarquin, J.M. Gonzalez and R. Bressani. 1974a. Comparación y utilización del cerdo criollo y Duroc-Jersey en cuanto a crecimiento y utilización del alimento. Turrialba 24: 29-34.

Gomez-Brenes, R., R. Jarquin, J.M. Gonzalez and R. Bressani. 1974b. Crecimiento, utilización del alimento y proteínas séricas del cerdo criollo y del Duroc. Resumen IV Reunión ALPA, Guadalajara, México. Memorias ALPA 9: 35-36.

Gomez-Brenes, R.A., R. Jarquin, C.E. Acevedo, J.M. Gonzalez and R. Bressani. 1975. Estudios sobre necesidades nutricionales del cerdo criollo: Proteínas. V. Reunión ALPA. Maracay, Venezuela.

Goonewardena, L.A., Sahaayaruban, R., Rajamahendran, R. & Rejagura, A.S.B. 1984. A study of some production traits among indigenous pigs in Sri Lanka and their crosses with improved white breeds. Wld. Rev. Anim. Prod. 20: 45-50.

Kleeman, G., M.F. Guerrero, G. Gomez, J. Maner, J. Buitrago and A. Owen. 1975. Comparación de rendimientos de razas de cerdos criollos (Zungo) colombianos, Duroc y sus cruces en zonas tropicales. V Reunión ALPA. Maracay, Venezuela.

Ministerio de Agricultura y Gandería (El Salvador). 1984. Informe al IDRC sobre trabajos realizados en 1982-1983 en el Proyecto: Mejoramiento de la Productividad del Cerdo Criollo en El Salvador.

Paladines, O. 1988. Analisis de la producción de ganado vacuno y leche, ganadoporcino, cámelidos y cuyes en América Latina continental. In: Escobar, G. (Ed.). Latinamerican Selected Commodities, CIID, Bogotá (In press).

Pathiraja, N. 1986. Mejoramiento de la producción porcina en los paises en desarrollo. 1. Explotación del vigor híbrido (heterosis). Revista mundial de zootecnia, 60: 18-25.

Pathiraja, N. 1987. Mejoramiento de la Producción Porcina en los Países en Desarrollo. 2. Planes de Selección. Revista Mundial de Zootecnía, 61: 2-10.

Quijandría, B. 1984. El mejoramiento Genético de Porcinos. U.N.A. Lima, Perú.

Quijandría, B. 1979. Swine production system in Central America: Limiting factors, prospects and research requirements. 11th Occasional Meeting. British Society of Animal Production "Intensive Animal Production in Developing Countries". 11-14 Nov. Harrogate, England. CATIE, Turrialba, Costa Rica. 22p.

Quijandría, B. 1981.

Rigor, E.M. & Kroeske, D. 1972. Razas porcinas indigenas y exóticas de los trópicos. Revista Mundial de zootecnia, 4:20-24.

Sutherland, R.A., Webb, A.J. and King, J.W.B. 1985. A survey of world pig breeds and comparisons. Anim. Breed. Abs., 53 (1): 1-22.

Ventura, J.A. 1987. Informe Anual Proyecto Mejoramiento de la Productividad del Cerdo Criollo en El Salvador. MAG. Centro de Desarrollo Ganadero. El Salvador.

Wilkins, J.V. and Martinez, M. 1983. Bolivia-Estudio sobre la productividad porcina en las aldeas de los llanos húmedos. Revista mundial de zootecnia, 47: 15-18.

5.6 Guinea Pig

Aliaga, L. 1974. Selección y Mejora de Cuyes. En "Investigación en Cuyes". 1: 31-44.

Chauca, L., Quijandría, B., Saravia, D. and Muscari J. 1984. Evaluación de la Tasa de Crecimiento, Tamaño de Camada y Conversión Alimenticia de Cuatro Líneas de Cuyes. En "Informe Anual". EEA, La Molina.

Chauca, L., Saravia, J. and Muscari, J. 1984. Mejoramiento por Selección del Cuy o Cobayo Peruano. En "Informe Anual". EEA, La Molina.

Dillard, A., Vaccaro, R., Lozano, J. and Robison, O. 1972. Phenotypic and Genetic Parameters for Growth in Guinea Pigs. "Journal of Animal Science" 34: 193-195.

INIPA. 1984. Informe Anual. Estación Experimental Agropecuaria, La Molina. Proyecto Animales Menores. Lima, Perú.

INIPA. 1985. Informe Anual. Estación Experimental Agropecuaria, La Molina.

Quijandría, B. 1982. Single Trait and Index Selection for Litter Size and Body Weight in Guinea Pigs. Thesis Degree of Doctor of Philosophy. North Carolina State University. Raleigh. 83 pp.

Quijandría, B., Chauca, L., and Robison, O. 1983. Selection in Guinea Pigs. I. Estimation of Phenotypic and Genetic Parameters for Litter Size and Body Weight. "Journal of Animal Science". 56: 814-819.

Quijandría, B., Muscari, J. and Robison, O. 1983. Selection in Guinea Pigs. III. Correlated Responses to Selection for Litter Size and Body Weight. "Journal of Animal Science". 56: 829-832.

Quijandría, B., Zaldivar, M. and Robinson, O. 1983. Selection in Guinea Pigs: II Direct Response for Litter Size and Body Weight. "Journal of Animal Science". 56: 820-828.

Quijandría, B. 1987. Producción de Cuyes. FAO Animal Production and Health Paper. (In Press).

Saravia, J., Chauca, L. and Muscari, J. 1984. Mejoramiento por Selección del Cuy Tipo 4. En "Informe Anual". EEA, La Molina.

Vaccaro, R., Dillard, E. and Lozano, J. 1968. Crecimiento del Cuy del Nacimiento al Destete. Memoria de la Asoc. Latinoamericana de Producción Animal. 3: 115-126.

5.7 South American Camelids

Bustinza, V. 1985. Mejoramiento de la Alpaca. Universidad Nacional del Altiplano, Puno. Primer Informe.

Bustinza, V., G. Mamani, G. Medina and D. Olarte. 1985. Prueba de Progenie en Alpacas. V Convención Internacional sobre Camélidos Sudamericanos. Cuzco, Perú. (Abstract).

Calle, R. 1979.

Calle, R. 1982. Producción y Mejoramiento de la Alpaca. Banco Agrario del Perú.

Espinoza, G. 1979. Determinación de la Edad al Destete en Alpacas. IV Reunión Nacional de Ganadería, Trinidad, Bolivia.

Rodriguez, T. and Z. Martinez. 1979a. Determinación de la Edad al Destete en Llamas. IV Reunión Nacional de Ganadería. Trinidad, Bolivia.

Rodriguez, T. and Z. Martinez. 1979b. Ritmos de Crecimiento en Llamas. IV Reunión Nacional de Ganadería. Trinidad, Bolivia.

Roque, J., M. Carpio and R. Blackwell. 1985. Transmisión Hereditaria de Peso Vivo y Longitud de Mecha en Alpacas. V Convención Internacional sobre Camélidos Sudamericanos. Cuzco, Perú. (Abstract).

Sumar, J. 1985. Reproductive Phisiology in South American Camelids. In "Genetics of Reproduction in Sheep". R.B. Land and D.W. Robinson, Editors. Butterworth, London.

Velasco, J., N. Condorena, D.D. Kress, P.J. Burfening and R. Blackwell. 1981. Breed Characteristics, Color and Weight Inheritance in Alpaca. J. Anim. Sci. 54:156 (Abstract)

ANNEX I. PREVAILING FARMING SYSTEMS IN THE DEVELOPING WORLD

TABLE I.1 PREVAILING SYSTEMS OF AGRICULTURE ON SMALL FARMS, MAIN REGIONS OF USE, MAJOR CROPS AND ANIMAL SPECIES, AND FEED SOURCES FOR ANIMALS OF ASIA.

Farming System	Major Crops	Major Animals	Regions*	Main Feed Sources
1. Coastal fishing and farming complexes, livestock relatively important	Coconuts, cassava, cacao, rice	Swine	P, T	Coconut by-products,rice bran
		Ducks	TW,T,M, P,I	Marine pro-ducts,rice bran
		Cattle and goats	SL,P,M, I	Pastured with coconuts
2. Low elevation, intensive vegetable and swine,livestock important	Vegetables	Swine	C,TW,HK	Sweet potato residues,rice bran,fermented residues from vegetab.crops
		Ducks	HK	Crop residues, imported feeds
		Swine,fish	TW,M	Crop residues, rice bran
3. Highland vegetables and mixed cropping (intensive), live-stock important	Vegetables, rice, sugarcane, sweet potatoes, Irish potatoes	Buffalo, Cattle	P,T	Crop residues, rice bran, cut forage, sugar-cane tops
		Sheep,goats	I	
	Vegetables	Swine	P	Crop residues, waste vegetab.
	Rice	Cattle, buffalo	Asia	Crop residues
4. Upland crops of semiarid tropics, livestock important	Maize, cassava, sorghum,kenaf, wheat, millet, pulses, oilseeds, peanuts, etc.	Cattle, buf-falo, goats, sheep, poul-try, swine	IN,T	Bran, oilseed cake, straw, stovers,vines, hulls, hay
5. Humid uplands, live-stock important	Rice,maize,cassa-va,wheat,kenaf, sorghum,beans	Swine,poul-try,cattle buffalo	Asia (1000 mm rain)	Stover,weeds, by-products, sugarcane tops
	Sugarcane	Cattle, buffalo	T,P,I	Sugarcane tops crop residues
6. Lowland rice, in-tensive livestock	Rice,vegetables, pulses,chick-peas, mung-bean,sugar-cane	Cattle,buf-falo, swine, ducks,fish	Asia	Crop residues, weeds,by-pro-ducts, sugar-cane, tops

Farming system	Major Crops	Major Animals	Regions*	Main Feed Sources
7. Multistory (perennial mixtures), Livestock some	Coconuts,cassava, bananas,mangoes, coffee	Cattle,goats, sheep	P,IN	Cut and carry feeds from croplands
	Pineapple	Cattle	P,I	Crop residue, by-products
8. Tree crops (mixed orchard and rubber, livestock some importance	Orchard,trees, rubber,oil palm	Cattle,goats, swine	P,M, South T	Grazing or cut and curry
9. Swidden, livestock important	Maize,rice,beans, peanuts, vegetables	Swine,poultry, goats,sheep	Asia	Animals scavenge
10. Animal-based	Fodder crops	Cattle, bufalo,goats, sheep	I,M,IN	Cut and carry fodder,crop residue

*C, China; HK, Hong Kong; IN, India; I, Indonesia; M, Malaysia; P, Philippines; SL, Sri Lanka; TW, Taiwan; T, Thailand.

Source: McDowell and Hildebrand. 1980. Integrated Crop and Animal Production: Making the most of resources available to Small Farms in Developing Countries. The Rockefeller Foundation.

TABLE I.2 PREVAILING SYSTEMS OF AGRICULTURE ON SMALL FARMS, MAIN REGIONS OF USE, MAJOR CROPS AND ANIMAL SPECIES, AND FEED SOURCES FOR ANIMALS OF AFRICA.

Farming system	Major crops	Major Animals	Main Regions*	Feed Sources
1. Pastoral herding (Phase I, L= 10^2)* animals very important (symbiotic relationships)	Vegetables (compounds)+	Cattle, goats, sheep	Savanna (Southern Guinea)	Natural rangelands, tree forage
	Millet, vegetables	Cattle, goats, sheep	Savanna (Northern Guinea and Sahel	Natural rangelands, tree forages, crops residues
2. Bush fallow (shifting cultivation, Phase II, L= 5-10), animals not important	Rice/Yams/Plaintains, Maize, cassava, vegetables, tree crops, cocoyams, yams	Goats, sheep	Humid Tropics	Fallow, crops residues
	Sorghum/Millet maize, sesame, soybeans, cassava, sugarcane, tree crops, cowpeas, vegetables, yams	Cattle, goats, sheep, poultry, horses	Transition, forest/savanna Southern Guinea, Northern Guinea and Sahel	Fallow, straws, stover, vines, cull roots, sesame, cake
3. Rudimentary sedentary agriculture (shifting cultivation, Phase III, L= 2-4) animals important	Rice/Yams/Plaintains, maize, cassava, vegetables, tree crops, cocoyams	Goats, sheep, poultry, swine	Humid Tropics	Rice bran, cull roots, straws, crop residues, vine, stover
	Sorghum/Millet maize, sesame, cotton, sugarcane, tree crops, cowpeas, yams, tobacco, ground nuts, vegetables	Cattle, goats sheep, poultry	Transition forest/savanna Savanna (Guinea and Sahel	Stover, vines, sugarcane, tops cull roots, or tubers, tree forage, groundnut cake, brans
4. Compound farming and intensive subsistence agriculture (shifting cultivation, Phase IV, L= 2), animals important	Rice/Yams/Plaintains, maize, cassava, vegetatables, tree crops, cocoyams, yams	Goats, sheep swine, poultry	Humid Tropics	Rice straw, rice bran, vegetable waste, fallow, vines, cull tubers or roots, stover, tree crops, by-products, palm oil cake

Farming system	Major crops	Major Animals	Main Regions*	Feed Sources
	Vegetables sugarcane, tobacco,sesame, maize,tree crops, groundnuts	Goats,sheep poultry, swine	Transition forest/ savanna	Vines,stover, tree crop,by-products, groundnut cake
	Vegetables/Millet cassava,cowpeas, tobacco,cotton, groundnuts,tree crops+++	Cattle	Savanna (Guinea and Sahel)	Vines,tree-crops, by-products, cassava leaves, fallow
5. Highland agriculture animals important	Rice/Yams/Plaintains, maize cassava,vegetables,plaintain, cocoyams	Goats,sheep, poultry, swine	Humid tropics	Fallow,leaves, stover,rice by products,cull tubers,cassava leaves,vegetables residues
	Sorghum Soybeans,cowpeas, cassava,maize, millet,groundnuts	Cattle,goats, sheep,poultry	Transition forest/ savanna	Stover,vines, groundnut cake
	Millet/Sorghum maize,groundnuts, cowpeas,sesame, tobacco,cotton, vegetables,cassava, yams	Cattle,goats, sheep,poultry,horses, donkeys	Savanna (Guinea and Sahel	Crop residues, some oil cake, brans,stover, vines, cull tubers
6. Flood land and valley bottom agriculture, animals of some importance	Rice/Yam/Plaintain maize,vegetables, sugarcane, rice, yams, cocoyams, millet,groundnuts	Goats,poultry	Humid tropics	Crop residues, vines,grazing
	Rice vegetables,maize, millet,groundnuts plantain, sugar-	Cattle,goats, sheep,poultry,swine, horses,donkeys	Transition forest/ savanna	Straw,stover, molasses, brans,groundnut cake
	Yams/Sugarcane maize,cowpeas, cocoyams,groundnuts,vegetables, plantains,rice, yams	Cattle,goats, sheep,poultry, swine, horses, donkeys	Savanna (Guinea and Sahel	Vines,brans, cull,tubers, molasses,sugarcane tops

Farming system	Major crops	Major Animals	Main Regions*	Feed Sources
7. Mixed farming (farm size variable; animals important)	Rice/Yams/Plaintains	2 or more species (widely variable)	Humid tropics	Fallow,straw, brans,vines
	Rice/Vegetables yams, cocoyams	Some cattle	Transition forest/ savanna	Fallow,vines, straw
	Sorghum/Millet groundnuts, cotton,tobacco, maize,cowpeas, vegetables	Cattle,goats, sheep, poultry,horses, donkeys,camels	Savanna (Guinea and Sahel)	Stover,vines, fallow
8. Plantation crops, East Africa (small holdings),animals of some importance	Coconuts vegetables, maize,plantains, cocoyams, cassava	Cattle,horses, donkeys	Humid tropics Transition forest/savanna	Grazing or cut and carry
9. Plantation crops, (compound farms, etc),animals of some importance	Cacao vegetables, maize, plantains	Goats,sheep, poultry, swine	Humid tropics	Grazing or cut and carry, stover
	Tree crops sugarcane, plantains	Goats,sheep, poultry, swine	Transition forest/ savanna	Grazing or cut and carry, sugarcane tops
10. Market gardening (animals may or may not be present)	Vegetables++	Variable	Humid tropics Transition forest/ savanna	Natural rangelands, crop residues, browse plants, range forbs

*L = C+F/C; L, land-use factor; C, area of cultivation; F, area in fallow.

+Enclosed areas around household or village.

++Present or absent, depends on area.

Source: McDowell and Hildebrand. 1980. Integrated Crop and Animal Production: Making the most resources available to Small Farms in Developing Countries. The Rockefeller Foundation.

TABLE I.3 PREVAILING SYSTEMS OF AGRICULTURE ON SMALL FARMS, MAIN REGIONS OF USE, MAJOR CROPS AND ANIMAL SPECIES, AND FEED SOURCES FOR ANIMALS OF LATIN AMERICA

Farming system	Major crops	Major Animals	Regions*	Main Feed sources
1. Perennial mixtures (large farms; livestock relatively unimportant)	Coconuts,coffee, cacao,plantains, bananas,oil palm, sugarcane,rubber	Cattle,swine	All	Natural pastures, by-products,cull material
2. Commercial annual (medium to large farms,livestock moderately important)	Rice,maize,sorghum,soybeans, small grains	Swine,cattle, poultry	All except CI	Pasture, crop residues,grain
3. Commercial livestock				
a. Extensive				
Large to very large,livestock dominant	None are important	Cattle(beef)	C,V,Br, Bo,G,CA	Natural grasslands
b. Intensive				
Medium to large, livestock dominant	Improved pasture, some grains	Cattle(dairy) swine,poultry	All	Natural and improved pasture, feed grains, by-products
4. Mixed cropping Small size in settled areas Medium size in frontier areas Subsistence or monetized economy Livestock relatively important	Rice,maize,sorghum,beans,wheat, cacao,plantains, coffee,tobacco, andean crops potatoes	Cattle,poultry,goats, sheep,donkeys, horses,mules, swine,alpacas llamas,guinea pigs	All	Natural pastures,crop residues,cut feed

*All, all countries; Bo, Bolivia; Br, Brazil; C, Colombia; CA, Central America; CI, Caribbean Islands; E, Ecuador; G, Guyanas; P, Perú; V, Venezuela.

Source: Modified from: McDowell and Hildebrand. 1980. Integrated Crop and Animal Production: Making the most resources available to Small Farms in Developing Countries. The Rockefeller Foundation.