GENETIC ASPECTS OF ADAPTATION OF ANIMALS TO TROPICAL ENVIRONMENTS WITH SPECIAL REFERENCE TO SHEEP AND GOATS IN NORTHEAST BRAZIL

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Abstract – A large portion of the world's population of domestic ruminants is found in tropical regions. This is especially true for goats. Productivity of domestic animals, found in the tropics, is substantially below that of temperate regions. If the productivity of animals found in these regions could be improved, the gap between human food needs and food supplies would be narrowed. This is particularly true for foods of animal origin. Tropical environments may adversely affect animal production in both direct and indirect ways. The direct pathways may be through the effect of high temperatures or temperature stress on the ability of the animal to live and function under prevailing conditions. Indirect ways may involve such constraints as feed intake, feed quality, available genotypes and disease or parasite burden. In the practice of animal agriculture, survival or persistence alone cannot be used as the measure of suitability, since productivity is the goal. There may be negative relationships between some measures of adaptation and productivity. In general, selection within or between genotypes, under prevailing environmental conditions, is indicated. Genetic progress may, in some cases, be enhanced by selection for other variables known to be related to adaptation. In the case of goats and hair sheep in Northeast Brazil, the indirect effects of climatic variables are likely more important than the direct effects. Genetic approaches to improving productivity might consist of; (a) systematic crossbreeding, (b) selection within native types, (c) developing new breeds from crossbred foundations or (d) breed substitution. It is suggested by the authors that systematic crossbreeding may be the most efficient means of improving production, but it may be difficult to implement the appropriate systems under smallholder conditions. In this case selection within existing types or crossbred foundations would be indicated. Selection within native or indigenous types will likely yield a slow response. Breed substitution to more productive breeds of temperate origins would seldom be indicated unless intense management can be practiced.

Aspectos genéticos da adapação de animais em ambientes tropicais, com especial referência a ovinos e caprinos no Nordeste do Brasil

Resumo – Uma elevada porção de ruminantes domésticos do mundo é encontrada em regiões tropicais. Isto é especialmente para caprinos. A produtividade dos animais domésticos nos trópicos é substancialmente inferior à das regiões temperadas. Se se

pudesse melhorar a produção animal nessas regiões, a diferença entre as necessidades humanas de alimentos e o suprimento seria diminuída. Os ambientes tropicais podem afetar adversamente a produção animal de maneira direta e indireta: diretamente, através do efeito das altas temperaturas, sobre a habilidade do animal de sobreviver e funcionar nas condições reinantes; indiretamente, através de restrições, tais como ingestão de alimentos, qualidade do alimento, genótipo disponível e carga de doenças e parasitas. Na prática da agricultura animal, a sobrevivência ou persistência sozinhas não podem ser usadas como medida de adequação, uma vez que a produtividade é que constitui o objetivo. Podem existir relações negativas entre algumas medidas de adaptação e a produtividade. Em geral, é indicada a seleção dentre e entre genótipos, sob as condições ambientais predominantes. O progresso genético pode, em alguns casos, ser incrementado pela seleção de outras variáveis conhecidas como relacionadas com a adaptação. No caso de caprinos e ovinos deslanados no nordeste do Brasil, os efeitos indiretos das variáveis climáticas são, possivelmente, mais importantes do que os diretos. As abordagens genéticas para melhoramento da produtividade podem consistir de: a) cruzamento sistemático, b) seleção dentre tipos nativos, c) desenvolvimento de novas raças a partir de fundações cruzadas e d) substituição de raças. Os autores sugerem que o cruzamento sistemático pode ser o meio mais eficiente de se melhorar a produção, mas pode ser difícil implementar os sistemas adequados nas condições dos pequenos proprietários. Neste caso, a seleção dentre os tipos existentes ou fundações cruzadas seria indicada. A seleção nos tipos nativos ou indígenas provavelmente obterá uma resposta lenta. A substituição de raças por outras mais produtivas e regiões temperadas dificilmente seriam indicadas, a não ser por práticas de manejo intensivo.

Introduction

A large portion of the world population of domestic ruminants is found in tropical regions. Seifert (1984) stated that 64%, or 800 million, of the world's cattle population is found in the tropics; however (German Federal Republic 1974) had previously stated that almost 1/2 of the earth's 1,200 million cattle are in the tropics, i.e. between the Tropic of Cancer and the Tropic of Capricorn. Sheep and goats are largely concentrated in the semiarid zones just south and north of the two tropics. In terms of goats, Shelton et al. (1984) stated that "over two thirds" of the world's goat population is found within 30^{o} of the equator, which includes 7^{o} of latitude North and South of the tropics of Cancer and Capricorn, respectively. Sheep have been less successful in penetrating the tropics, and some estimates (Williamson & Payne 1978) suggest that 19-20% of the world's sheep is found in tropical regions (Table 1).

There are major differences in the type of sheep in various geographic and climatic

TABLE 1. Percentage of animal populations found in the tropics.

Cattle	64	Seifert (1984)
	50	Rendell (1974)
Sheep	20	Williamson and Payne (1978)
Goats	66	Snowder, Shelton, Figueiredo (1984)
	54	Williamson and Payne (1978)
Buffalo	38	Williamson and Payne (1978)

regions. Very few wooled sheep are found in the humid tropics, although most of the world's sheep are wool producing types. This may provide a satisfactory explanation for the limited numbers in tropical regions. Sheep found in the humid tropics are largely hair sheep. Large numbers of wooled sheep, primarily of Merino or Fat-tail type, are found in the arid subtropics. Among the possible explanations for the large numbers of animals in tropical regions are the large surface area around the equator, particularly as contrasted to polar regions and the forage production potential of tropical regions due to abundant land area, moisture, sunlight and warm temperatures.

It is generally recognized that the productivity of animals located in the tropics is below that of the temperate regions. As an example of this, Sahni & Chawla (1982) summarized the milk production from dairy goats in temperate and tropical climates. In general, the same breeds maintained in tropical environments produced only 50-60% as much as those in temperate regions. FAO data (interpreted by Williamson & Payne 1978) suggest that annual per head milk production from cows in the tropics is only approximately 20% of that of some temperate regions. Reduced growth rates and poor reproductive efficiency have been reported for unadapted breeds of cattle introduced to tropical conditions (Vianna & Jondet 1978). This depression of production may well represent the multiple effects of a tropical environment which includes not only the direct effect of environmental stress, but indirect effects through type of livestock (species or breeds), diet quality and production systems imposed by socio-economic constraints.

The statements above, appear to clearly indicated that a large number of domestic ruminant animals are found in the tropics and that in general, their productivity is substantially below that of temperate regions. In some cases, the opportunity for improvement is several multiples of that currently being realized. If this disparity could be even partially overcome, the end result would be a marked improvement in the contribution to meeting man's needs. It may be significant to note that domestic ruminants did not evolve or were not domesticated in the tropics and in most cases, have been moved into the tropics in relatively recent times.

Mechanisms of adaptation

The mechanisms by wich tropical environments reduce animal performance are many, and will no doubt, be dealt with in other reports. It should be pointed out that there may be a direct effect of high temperature stress on animal performance at a given time and place. For instance, if an animal is having difficulties in maintaining its body temperature within the normal range, foraging and other productive activities will suffer. There are also many indirect ways in which production may be affected. One of these would be the inability to utilize the more productive breeds or genotypes in tropical environments. An additional factor which may be only indirectly related to tropical environments are socio-economic constraints which prevent the implantation of the most production systems.

Some of these points warrant further discussion. Many genotypes which are most productive in temperate climates simply cannot be produced on a practical basis in the tropics. Examples of these are the Merino sheep for wool production, Suffolk sheep for growth, Saanen goats for milk production and Angora goats for fiber production. A number of breeds of beef or dairy-type cattle might be added to this list. Those types which are exploited in the tropics are markedly lower in many aspects of productivity, even in temperate climates or improved conditions. This suggests a negative relationship between productivity and adaptation to adverse climates. This phenomenon has not been adequately investigated.

Poorly adapted animals may be lost through the multiple effects of stress, disease and parasites. Another major area of loss is poor reproductive efficiency. There are at least four ways in which high temperature stress can contribute to poor reproductive efficiency. These are: (a) failure to cycle, (b) reduced semen quality of heat stressed males (Lindsay 1969), (c) loss of the zygote within the first eight days after conception (Dutt et al. 1959), and (d) fetal dwarfing due to high temperate stress during gestation (Shelton 1964 and Thwaites 1969). Cummulatively, these problems can preclude production of an unadapted animal under heat stressed conditions. Conversely, well adapted types such as hair sheep and native types of goats often exhibit high levels of reproduction in tropical environments.

Nutrition of the ruminant animal in the tropics may suffer in direct and indirect ways. Tropical forages, more especially tropical grasses, are generally low in feed value. High fiber diets contribute to increased stress due to the heat produced as a byproduct of digestion, and there will be reduced forage intake to compensate for this. These problems can be largely overcome through feeding of high energy feeds, but economic constraints often preclude this practice.

In the absence of an ability to alter the environment, animal breeding assumes a high priority in improving productivity in unfavorable environments. It should be pointed out that the animal must not only be adapted, but must also serve a useful role. To be adapted may require only that the animal be able to survive and reproduce in a given environment, but not necessarily be highly productive of meat, milk, fiber, etc. There are few examples of successful animal industries on any scale which are not based on an adapted and productive genotype.

There is a need to distinguish or define adaptation and acclimatization. Adaptation is defined as an alteration or adjustment, often hereditary, by which a species or population evolve in relation to its environment (Morris 1969). This definition is clearly differentiated from acclimatization, defined by Folk (1982), as the physiological changes that occur in an individual animal exposed for days or weeks to an extreme condition of environment so that its tolerance (survival and productivity) is extended. In respect to animal breeding, it is the former with which we are concerned, although, genetic differences in the acclimatization ability of the animals may fit under the heading of adaptation. Adaptation is, for the most part, thought to be determined by additive genes (i.e., a quantitative trait), but the additive genes responsible for adaptation and for production may not be the same; in fact, observation tends to suggest the opposite (Frish & Vercoe 1982).

Long term genetic change in stressing environments would appear to be accomplished by emphasizing the desired productive traits within the prevailing environmental and production conditions. However, if individual environmental constraints can be identified and the animals reaction to these can be quantified, genetic change can be enhanced by simultaneous selection for production and by use of selected measures of adaptation. Thus there is a need to identify those measurable traits which contribute to fitness.

Domestic ruminants have a relatively constant body temperature (homeostasis), despite variable environmental temperatures, through very sensitive and fast acting mechanisms. A failure to maintain body temperatures within normal ranges may results in death. Some non-domestic species are able to tolerate a much wider range in body temperatures. This phenomenon deserves more attention in domestic animals.

There are a number of physiological mechanisms utilized by individual animals or by evolving populations to respond to high temperature stress. Such mechanisms are present in a larger or smaller degree in cattle, sheep and goats and also present some variations in terms of relative efficiency across breeds and species. The most important are:

1. Evaporation
2. Decreased insulation
3. Decreased heat production
4. Reduced heat absorption
5. Increased heat loss

Evaporation of moisture constitutes a primary means of control of body temperature. In some species this is accomplished through sweating. Domestic ruminants, in general, do not have well developed and functional sweat glands but there is genetic variability between species, breeds and individuals. Even in the absence of true sweating, there is some moisture loss from the skin. In the absence of extensive sweating, increased evaporation from the respiratory passages is a primary means of heat loss. Thus, as the animal is subjected to heat stress, there is an increased respiratory rate or panting. A measurement of respiratory rate becomes an easy and practical means of appraising stress. Selection based on low respiratory rates should contribute to adaptability. High temperature stress, as indicated by an elevated respiratory rate, interferes with many functions associated with productivity. Also, it makes the less adapted animal highly dependent on readily available water sources.

Insulation, particularly that of a fleece or extensive hair coat, interferes with heat loss from the body. The most noted example of this is the fleece of wool producing sheep which is an obvious disadvantage in tropical climates. Animals which are allowed to evolve in a tropical climate will develop less fleece cover. As a management practice, wool-producing sheep should be shorn more frequently in tropical environments. The coat of animals normally consist of two types of fibers derived from primary and secondary follicles. The latter gives rise to the down or undercoat which has good insulating properties and is thus undesirable in tropical areas. There are large differences in the development of the two types of fibers and the absence of the down is looked on as a measure of adaptation to high temperature stress. A short, glossy coat of fibers derived from the primary follicles reflects solar radiation and allow ready convection of body heat from the skin surface. Thus, selection for this type of coat appears to be indicated. However, a word of precaution is necessary. Even in tropical or subtropical areas some type of cold stress may be encountered. This appears to be particularly critical with goats. Thus, type of coat desired may be a compromise between the two extremes. It is possible that a hair coat or fleece can be advantageous in reducing heat stress but this can be true only under a very specific set of conditions which are only found under limited conditions. For instance, sheep with partial or full fleece have an advantage over a shorn animal when exposed to direct sunlight and when environmental temperature approaches or exceeds body temperatures (Shelton 1976) for several hours throughout the day.

Decreased heat production was enumerated as one mechanism for dealing with heat stress. This is most readily accomplished through reduced physical activity (travel or foraging), decreased intake of high fiber forages and through decreased metabolic activity. All of these would likely have a negative impact on production and are thus contraindicated as a means of selection. These factors should be considered in the design of appropriate management systems. For instance, the use of high energy rations contributes to the maintenance of production during times of heat stress.

The major source of heat from the environment is through absorption from the environment or from the radiant effects of the sun. The latter has little relationship to selection but may be a factor in management as the provision of shade will materially reduce heat stress.

Another factor relating to heat absorption is color. The familiar color variations in animals are genetically controlled (Wright 1959 and Adalsteinsson 1974), and are therefore amenable to selection. Light-colored hair, such as white or cream, reflects a higher proportion of the heating, infrared wavelengths than red and particularly black hair. A white smooth coat is associated with lower body temperatures rise than rough dark pelage. The black pigmentation (melanin) in the skin completely absorbs the erythematous (sun-burning) ultraviolet radiation. Non-pigmented skin is highly susceptible to sunburn and photosensitization disorders. Perhaps the ideal combination is a white, light or cream coat overlying dark skin. This is characteristic of many indigenous breeds in tropical areas. Animals with pigmented eyelids have less problems with eye cancer.

Increased heat loss by the animal results from evaporation, as discussed earlier. Other factors relate to body surface area relative to body mass. Adaptive, morphological modifications of animals are readily apparent in their conformation, e.g., body size and shape, length of legs and size of ears. The extent of heat exchange between an animal and its surroundings depends partly on body surface area. Smaller animals have a larger surface area per unit of body weight, and this may be a partial explanation for the small size of many tropical breeds. Species and breeds which evolved in cold climates have a large body size with a relatively small surface area. Climatic accomodation of animals is manifested to a certain degree by the length of their legs. For example, animals that normally inhabit desert areas tend to have long legs. In part, this is an adaptation for protection from the reflected heat of the earth's surface as well as an effective mode of locomotion or means of browsing from trees and shrubs, with the least expenditure of energy.

The ears represent a mass of tissue that have a high ratio of surface area to weight. Certain specialized structures in the vascular supply of the ear might aid considerably in heat dissipation in several species. Added skin surface may be found in the dewlap or underline. It appears obvious that this contributes to adaptation to heat stress, but attempts to measure the effects of this added skin surface have not shown marked differences. Sheep, like cattle, have special adaptive features to suit their environment. Northern desert sheep, found principally in the Mediterranean and Northern Sahara area are less compact, have longer legs and ears, and have hair and wool that are coarser and less compact. Sheep in these areas have the typical fat tail of the desert types. In the southern Sahara and southern Indian deserts, the sheep have fine, long rangy bodies, long legs, elongated necks, long ears and tail and fine short hair. These sheep are typically fat rumped (Hafez 1968).

Genetic approaches

Genetic approaches to improving productivity in unfavorable environments might include any or all of the following approaches:

1. Continuous and systematic crossbreeding,
2. Selection within native and adapted types,
3. Development of new breeds from crossbred foundations,
4. Grading up to improved types.

Crossbreeding Systems

Crossbreeding systems have been successfully used in the livestock industry to utilize superior breeding value for the individual traits desired, heterosis (Dickerson 1969, Willham 1970 and Cundiff 1970) and breed complementarity, as in the use of dam and sire lines (Cartwright et al. 1964) and the general and specific combining ability (Henderson 1952), resulting from crossbreeding. These multiple advantages and the marked gain realized from the use of crossbreeding suggests that this approach will continue to be important.

One strength of crossbreeding systems is its use of genetic diversity among breeds. According to Dickerson (1969) the relative efficiency of various crossbreeding schemes, as compared to purebreeding, depends on several considerations: the magnitude of breed differences in individual versus paternal performance of straightbred; the magnitude of crossbreeding heterosis for individual, maternal and paternal performance; the loss in epistatic superiority of straightbreds due to the recombination of gametes produced by the crossbred parents; the reproductive rate of the species, and the importance of interactions of genetic components with management and (or) marketing systems. It is the author's thesis that where native, adapted but low producing types are available, along with more productive exotics, crossbreeding offers the most immediate means of improving productivity.

Rotation crossbreeding requires only male replacements from purebred matings and utilizes a high proportion of the maximum potential heterozygosity; recombination effects are kept relatively low since only the female parents produce recombination gametes. However, there is the disadvantage that the same average genotypes must be accepted for individual and maternal performance, except for that controlled by the sex chromosome. Also, there is less opportunity for adaptation to particular environments since half of the progeny and dams genotypes are determined by the breed of sire last used.

Some of the advantages of specific and rotation crossbreeding can be combined by mating males from a superior sire breed to females produced through a rotation crossbreeding program designed to maximize maternal heterosis. Maternal heterosis can therefore be utilized with relatively little handicap from recombination effects. Breed differences in both maternal and paternal performance can thus be used with a source of pure bred sires as the sole requirement.

No work has been reported on estimating heterosis in crosses of some of the tropical sheep breeds. For tropical meat production, crosses among the hair breeds seems well worth exploring (Turner 1974); an analogy is the level of heterosis exploited in beef cattle production.

Angwenyi (1984) found that despite their lower body weight, East African goats had higher kid survival from birth to weaning (.96) compared to Galla (.85) and to Boer (.70) breed of goats. In his study, he also found that Boer additive effects were positive and higher than Galla and East African additive effects for body weight and conformation. Galla, however, presented positive maternal additive effects for body weight and growth rates and percent of kid survival. It was concluded that for their conditions in Kenya, the East African goat has to be maintained in the crossbreeding system of its adaptation to the local environment, the Galla for its superior maternal additive effects and the Boer for its direct additive effects for carcass value.

The crossbreeding approach presents some problems in the tropical regions such as that of finding parental breeds well adapted to produce efficiently but sufficiently unrelated to produce significant heterosis when crossed (Frisch & Vercoe 1982). Also, the continued improvement of the crossbreds relies on improvements of the parent breeds which often are not selected in the tropical environment.

Selection within the native types

In general, native types show high degree to adaptation to their home environment due to prolonged periods of natural selection for adaptation (De Alba 1978). Usually, such animals present low genetic variability for various production parameters. This may result from inbreeding depression and the fixation of alleles responsible for fitness (Turner & Young 1969), which makes the genetic response very slow. The generally low production suggests that the genes responsible for adaptation are not the same as those responsible for productivity and as a result selection within the native breeds may yield slow progress. Crossbreeding systems often provide a better alternative for early improvement in productivity. Also, selection based on crossbred foundations may yield better response than in those cases where selection is rendered ineffective due to exhaustion of additive genetic variability. Although crossbreeding often provides a better alternative for early improvement in production, selection within local types offers some advantages in specific cases where the current product type must not be changed, although quantity or quality can be improved (Turner 1974). Another reason for selecting within adapted types is when good breeds for crossing do not exist. Also, improvement programs within native types are important even when they are used in crossbreeding systems.

Frisch & Vercoe (1982) postulated that

selection for growth rate under continued stress would lead to an animal with high adaptation but low growth potential. Conversely, selection under continued low stress lead to a genotype with high growth potential but low adaptation. Therefore, the selection of exotic breeds for growth in stressful environments will exert pressure on those traits which most limit growth, in this case adaptation (Frisch 1981). Consider the conflict between the need for high heat tolerance and the high heat load associated with high food intake and metabolism. If gene frequencies for heat tolerance traits are low and gene frequencies for growth potential high, selection for growth in the presence of heat stress may initially operate to enhance heat tolerance and to decrease high growth potential (Seifert 1984). However, where the tolerance traits improve to the point where they are no longer the most limiting factor, selection would again be directed towards growth potential.

It appears that the genetic improvement will be accelerated if some other genetic improvement method is used in combination with selection. Therefore, selection within the native types remains an alternative for very specific cases or breeding purposes.

Development of new breeds

Because a high percentage of cattle, sheep and goats, on a global basis, are in herds which are to small to use well organized crossbreeding systems on a self-sustaining basis, composite breeds represent good alternative to continous crossbreeding systems. With this approach, the goal should be to achieve and maintain the most optimum additive genetic composition, aimed at combining general adaptability and performance characteristics within the production environment and market requirements.

There is some loss of initial heterozygosity following crossing and subsequent **"inter se"** matings. The loss of heterozygosity occurs between the F1 and F2 generations (Table 2). Retention of heterosygosity favors the inclusion of a larger number of breeds in composite populations.

Synthetic populations offer much the same opportunity as rotation crossbreeding for retaining individual and maternal heterosis, plus some heterosis in male reproductive performance in commercial matings. However, synthetics are subject to maximum recombination effects and do not permit use of different genotypes for male and female parents. The major advantage of composite breeds over rotational crossbreeding systems is the opportunity to achieve and maintain the most optimum contribution by each breed and to eliminate the need to maintain more than one breed or population.

Another potential advantage of composite breeds relative to rotational crossbreeding systems is that the response to selection may be greater in composite populations than in contributing parental breeds due to the increased genetic variation and greater selection intensity possibly within composite breeds, with their higher reproduction rate, a result of heterosis (Dickerson 1973). An important consideration in the development of composite breeds is to maintain a population size large enough so that the initial advantage of increased heterozygosity is not dissipated by early reinbreeding.

In practical terms, Dickerson (1969) criticized the development of new breeds from

TABLE 2. Fraction of heterosis (h), recombination (r) and differential maternal and paternal performance of dam and sire breeds ($g^m g^p g^m g^p$) expected for alternative system of breed use (Dickerson 1973).

Mating system	Heterosis			Recombination			Breed differences	
	h^i	h^m	h^p	r^i	r^m	r^p	$g^m g^p$	$g^m g^p$
2-breed cross								
(F1 AxB)	1	0	0	0	0	0	1/2	1/2
3-breed cross								
(CxAB)	1	1	0	1/4	0	0	1/2	1/2
(ABxC)	1	0	1	1/2	0	0	1/2	1/2
4-breed cross								
(CDxAB)	1	1	1	1/2	0	0	1/2	1/2
Rotation cross								
2 sire breeds	2/3	2/3	0	2/9	2/9	0	0	0
3 sire breeds	6/7	6/7	0	6/21	6/21	0	0	0
4 sire breeds	14/15	14/15	0	14/15	14/15	0	0	0
CxRotation								
2 dam breeds	1	2/3	0	2/9	2/9	0	1/2	1/2
3 dam breeds	1	6/7	0	6/21	6/21	0	1/2	1/2
4 dam breeds	1	14/15	0	14/15	14/15	0	1/2	1/2
Synthetic								
2 breed	1/2	1/2	1/2	1/2	1/2	1/2	0	0
3 breed	2/3	2/3	2/3	2/3	2/3	2/3	0	0
4 breed	3/4	3/4	3/4	3/4	3/4	3/4	0	0

h^i = individual heterosis / r^i = recombination loss, individual performance
h^m = maternal heterosis / r^m = recombination loss, maternal performance
h^p = paternal heterosis / r^p = recombination loss, paternal performance
g^m = breed effect in maternal performance
g^p = breed effect in paternal performance

crossbred foundations, because their genetic potential for commercial performance is generally regarded as lower than that of systematic 3-breed specific or rotational crossbreeding. However, new breed development may be indicated even when heterosis is important, if initial unfavourable recombination effects are negligible, especially when there are new objectives or radically altered management conditions, and in areas where simplicity of the breeding program is essential.

It is apparent that the reproductive rate and the relative magnitude of heterosis, recombination effects and of breed differences in individual maternal and paternal performance determine the most advantageous method of utilizing genetic differences among breeds. When individual and maternal heterosis is large, there is more advantage in crossbreeding or synthetic breeds over the pure breeds. When there are large differences in maternal or paternal performance or in adaptation to particular management system, it is advantageous to use some type or specific cross rather than rotational crossbreeding or synthetics. If the potential recombination loss is of importance, crossbreeding has greater advantage over synthetics as a means of utilizing existing breed differences. Of course, the lower the rate of reproduction, the greater the costs for specific crossbreeding systems and the greater the advantage in rotational crossbreeding or synthetic breeds.

Grading up to improved types

The validity of this approach depends on the definition of the term "improved types". If one envisioned the exotic types which are indeed more productive under the good feed conditions of temperate regions, then the term "improved" is probably not fitting under tropical conditions. Thus, grading up is not a fitting approach although it is often practiced. If an improved breed is defined as one which has been developed and tested in the same or in a similar environment, then it is indeed a fitting approach although it may require a long time period to identify or develop such a breed. From a breeding standpoint, the grading up process is simple and direct and can be accomplished efficiently. The period of time required to reach a high grade status (3/4 or higher) depends on the reproductive rate and generation interval. Although grading up can be accomplished efficiently, it has limited application in stressfull environments since highly productive and adaptive genotypes seldom exist in a single breed. It is seldon desirable to consider productive breeds from temperate regions as "target breeds" since they are poorly adapted to the stressful environment. Instead, to utilize the production characteristics of temperate zone breeds, one must make repeated crosses or establish an interbreeding population based on **"inter se"** matings. Thus the term "grading up" is not totally fitting. If this is not a constraint, the level of purity or percentage of the improved breed desired or required depends somewhat on the product produced. In the case of fiber, which has little application to the tropics, many generations are required to develop uniformly desirable fleeces. On the other hand, meat production from the 2nd or 3rd generation may approach that of the target breed. Milk productions is somewhat intermediate in this respect.

Suggested breeding plans for sheep and goats for Northeast of Brazil

Observations, along with limited research, (Arruda & Pant 1984 and Arruda et al. 1984) do not indicate a major direct effect of climate on the production of indigenous goats and hair sheep in Northeast Brazil. For instance, reproduction has been indicated as one trait which is greatly affected by high temperature stress. Yet, available data indicate that when adequate nutrition is provided, a satisfactory level of reproduction can be expected (Fernandes 1985). At this time it is not clear to what extent the indirect effects of forage availability or intake limits performance. Also, the above statement is applied to indigenous or native types and most likely would not equally apply to exotics. For certainty, wooled sheep introduced into Northeast Brazil would suffer from climatic stress.

Thus, with native types, selection for the desired production characters, within prevailing production conditions, would appear to be indicated. In selecting or evaluating exotics or selecting within crossbred populations, it may be desirable to include some measures of climatic adaptation. The simplest of these would be respiratory rate as an adjunct to survival and productivity.

Some attention might also be given to hair coat and color.

To determine a breeding plan for any particular region, it is necessary first to clearly specify the objectives of the production system for such a region. From the results obtained so far in sheep and goat research in Northeastern Brazil, it appears that sheep and goats, to some degree may serve different roles, although there is some overlapping of functions between the two species. Sheep may be more efficient than goats in terms of meat production, especially when grazing mixed vegetation, while goats appear to offer more potential than sheep for milk production. It is also likely that goats should continue to recieve emphasis where caatinga alone is the forage base. Both appear to be equally efficient in terms of skin production, since this is a byproduct equally important in both species.

For a region similar to the Northeast of Brazil, it seems obvious to direct the use of such species to produce more efficiently within the resources available. In this case, breeding programs with sheep would be directed at meat production. Breeding programs with goats might be directed at either meat and milk production, but the likelihood of marked improvement in respect to efficiency of meat production is not very good.

After deciding the biological objectives of a production system, the next step is to determine the management systems. To produce lambs economically and with a fast capital turnover, they should ideally be born and raised in the same season, namely the wet season, when there is plenty of feed available. In Northeast Brazil, the wet season ranges from March to July but forage, remains in good condition, until mid August (Figueiredo et al. 1980 & Pfister 1983).

Sheep

In respect to sheep, there are relatively few breeds found in the Northeast, and it is difficult to envision good candidate breeds for introduction to the area. The types found in the region include the Santa Ines, Morada Nova, Somali, Crioula and Rabo Largo. These are all hair sheep except for a vestigial type of fleece found on many Crioula.

The Somali and Rabo Largo are, no doubt, the most hardy types found in the region. Also, both, trace to types found in other parts of the world which are renowned for their hardiness. For instance, the Somali is obviously a derivative of the Blackhead Persian type, which is considered to be among the most hardy. The Rabo Largo traces to some type of "fat tail" sheep, many of which are renowned for their hardiness and adaptation to arid conditions. It seems logical to the writers that these types should be maintained and emphasized in the more arid regions of the interior of the Northeast. They might very well be blended into a single type, without emphasizing the presence of fat in the tail. These types could likely be improved by the introduction of new gene sources of the Somali or Blackhead to overcome genetic defects inbreeding depression and degeneration because of neglect or natural selection under tropical conditions. The resulting genotype should be selected under prevailing conditions emphasizing ewe productivity, lamb survival and growth rate of the offspring. Commercial-scale production from this type of animal would benefit markedly from crossbreeding to a sire breed, but it is difficult to implement this practice under conditions of much of Northeast Brazil.

The two breeds wich are most distinctive and unique to this region are the Morada Nova and Santa Ines. The Morada Nova is perhaps the older of these two breeds, but it is not found in large numbers or is not identified as such in producer surveys (Gutierrez et al. 1981). It is generally smaller, but has a higher lambing rate than Santa Ines. It seems to be reasonably well adapted to the region. These traits suggest the most obvious use of this breed would be as a dam breed. By definition, a dam line would be exploited to best advantage in a crossbreeding system and there are limitations to this in the area. However, the writers encourage this approach and the continued selection of the breed to serve this role. Selection programs would emphasize those traits mentioned along with general overall performance directed at improvement of their suitability as a dual purpose breed. Specific selection programs will be outlined in other reports.

The Santa Ines is the largest breed developed from crossing of the Morada Nova and Crioula with exotic types. This breed is larger than the Morada Nova and with lower lambing rates, or at least a lower twinning rate. Their relative position in respect to adaptation is not clear at present. This breed is increasing in numbers in Brazil and will likely continue to do so in the future. The breed may best serve the role of a general purpose breed or a sire breed for use in crossing to the Crioula or Morada Nova. Selection in this breed should probably emphasize survival, regularity of breeding and growth rate. Emphasis on multiple births is probably not indicated.

The Crioula (native or local) is a mixed type of sheep which constitutes the bulk of the population in the Northeast. It appears to represent a blend of all the breeds introduced to Brazil in modern times (Shelton & Figueiredo 1981). Selection within the current population is largely nonexistent. The most likely change in this population will consist of the introduction and grading up to Santa Ines. At the present this appears to be a viable approach. The major question to be resolved is the degree to which these should be transformed into Santa Ines. It is important that they retain adaptation to producer conditions.

In the preceeding paragraphs, mention was made of the use of a sire breed. None of the breeds currently found in Northeast Brazil adequately serves this role. Likewise, breeds such as the Suffolk, Hampshire and Texel which serve this role in other regions do not seem to offer a potential in this area. The alternatives which appear to offer potential in the Northeast are that of the Dorper, which might be imported, or the Santa Ines, which may be developed to serve this role. Sire breeds would be selected primarily for growth rate and carcass value. If they function truly as a sire breed, they may require only moderate adaptation. There is a danger in selecting the Santa Ines for a sire breed while also expecting them to serve a role as a general purpose breed. In theory, there is a need to decide which role this breed is to serve but in reality no mechanism exists to do so.

Goats

There are a number of "so-called" native breeds of goats in Northeast Brazil. The term native is relative since even those so classified no doubt arrived in Brazil in fairly recent times. The breeds involved include the Moxoto, Repartida, Caninde, and Marota and a larger population known as the SRD (not well-defined type). Limited research suggests that, except for the SRD, these breeds do not differ markedly and may, in some cases, be largely color variants. These types are all relatively low milk producers as compared to traditional dairy breeds but they may not be particularly inefficient in meat production. Two imported breeds, the Anglo Nubian and Bhuj, are widespread in the area; the latter comes directly from India and resembles the breed known as the Beetal in that country. In addition to these, most of the established dairy breeds have been introduced in limited numbers. The pertinent question is where do we go from here? The writers see little need to select goats in this region specifically for heat adaptation. Goats are relatively little affected by the direct effects of high temperature stress in this region. Thus selection should emphasize performance under prevailing conditions. Two problems which seem to be somewhat unique to goats under adverse conditions are abortion and kid mortality, problems that warrant attention in breeding programs.

It is the writers' belief that if goats are to be milked, the flock should countain some dairy breeding. It appears that the exotic breeds can be utilized directly in the Northeast if conditions are sufficiently well improved and controlled. The latter can likely be accomplished only in intense dairy programs which largely do not exist in the Northeast. This may not be the case in the future. Under more typical conditions something less than pure exotic breeding should be employed. It seems likely that systematic crossing is most effective but would be difficult to implement under smallholder conditions. Thus, initial crossing and grading up followed by "**inter se**" matings is the next alternative. The next question is how long should the grading up process continue. Research results in the Northeast are inadequate to answer this question. The writers suggest 1/2 exotic (SRD x Exotic) under small farmer conditions, 3/4 exotic under semi-intensive conditions and pure exotic under highly improved conditions. Another question to be faced is how to choose the appropriate exotic. It is the writers' belief that there is little basis for a choice between the Alpine dairy types (ie. Germany Improved Fawn Alpine, Saanen, Toggenburg) and that any would serve this role. There is some reason for the belief that Saanen is less well adapted to adverse conditions. The Anglo Nubian is a special case. Most SRD contains some Anglo Nubian genes and thus less heterosis would be expected. They also have shorter lactations, lower total milk yields, higher total solids content and perhaps better adaptation to tropical conditions. This suggests that the Anglo Nubians might be utilized for a home milk supply or for home-scale cheese making where the higher solids content might partially overcome the lower lactation levels.

Breeding goats for meat production presents a much more confusing picture. If total or overall efficiency could be measured, it is likely that the "so-called" native breeds produce meat as efficiently as alternative types which might be considered. Thus, there is a need to maintain or improve some, if not all, of these. Fortunately, individual breeders plus the Bank of the Northeast of Brazil (BNB) supported programs provide a mechanism for doing this but, as previously discussed, response from selection within these breeds is likely to be slow. An alternative or additional approach is to select within a crossbred foundation. One such approach would be to select within a cross involving Anglo Nubian and/or Bhuj. The Boer could be added to this list if it can be imported. Selection within these crossbred populations should perhaps emphasize survival, net reproductive rate (including abortions and kid mortality), growth rate and carcass value. Detailed suggestions on how this should be accomplished would be too voluminous to include at this point. A true breeding strain based on a crossbred foundation would be more useful if they were distinctive or recognizable in appearance. For this reason, the Moxoto and Caninde might be suggested as the foundation in which their unique characteristics could be maintained with the resulting animal to be known as the improved Moxoto and improved Caninde.

Who should carry out such breeding programs in Northeast Brazil? Under more favorable conditions, the private sector has generally served this role. However, in this region, there is a strong possibility that this should be an institutional endeavor but, if it is to be successful, it must be pursued energetically and effectively. This is not always the case with institutional programs.

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