BEEF CATTLE BREEDING IN THE TROPICS.

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SUMMARY

Beef cattle breeding policies and strategies in the tropics have changed over the years in an attempt to optimize production levels given constraints of climate and economic conditions. Because of the diverse ecological zones and production systems found in the tropics and the possibilities for significant genotype x environment interaction effects, no one breeding system or genotype would be efficient for all situations. Breeders are therefore faced with the task of identifying and developing genotypes and genetic combinations that will maintain a balance between specific production environments and the need for optimum levels of production. To achieve this, it is necessary to strengthen on-going research/breeding programs in order to provide the much needed basic information on indigenous breeds and types and on genetic parameters, that is necessary for the development of more relevant and sound breeding strategies. Conventional beef cattle breeding systems are in a broad sense, applicable in the tropics. However, in choosing an appropriate system, consideration should be given to the need to maintain the right genetic constitution for adaptation, the practicability of the system and the economic conditions. Although the potential for utilizing composite (synthetic) populations is there, the risks involved in breed development are high when compared to selection within the indigenous breeds. The limited resources available for long term breeding programs in developing countries, and the long generation interval in cattle, make it necessary to identify in advance those breeding strategies with the highest prospect for success. The ideal choice would be the program that gave the highest return to investment. The potential of biotechnology to enhance livestock improvement in the tropics should not be overlooked, the contribution of multiple ovulation and embryo transfer (MOET) in tropical beef cattle breeding is not so much in the industry but in the long term improvement programs such as selection and breed development as a technique to facilitate genetic gain. Promising developments in molecular genetics may in future make it possible to select for disease resistance in tropical livestock using genetic markers.

INTRODUCTION

Unless there are major changes in the production system, environmental conditions will always determine the types of livestock that can be used specifically in the harsh tropical regions, even though these types may not necessarily meet the growing demand for meat, milk and fibre. Natural selection has therefore produced genetic constitutions which provide tropical livestock populations with the capacity to survive and reproduce under these sub-optimal production environments. However, there are still variations in adaptation between some of the tropical populations, a typical example is the difference observed in the ability of cattle breeds in West Africa to tolerate trypanosomiasis challenge. The concerted effects
of genetics and behavioral mechanisms for adaptation have compromised on productivity.

Although beef production could be improved by using the less adapted but high potential temperate breeds, opportunities to alter the production environment to suit these breeds are limited by economic constraints. Genetic manipulation using existing variability within and among tropical cattle populations therefore remains an attractive option. Because of the sub-optimal production environment in the tropics, breeding policies and strategies should be developed to provide a balance between genetic resources and the environment in order to achieve sustainable levels of production. The strategies developed should also take into account the diverse production systems found in the tropics. Breeding programs in the past emphasized immediate but short term genetic improvements through extensive crossbreeding and upgrading of tropical beef cattle with temperate breeds. Current policies on beef cattle breeding in the tropics are aimed at using strategically available genetic resources to optimize production levels under specific environments, while at the same time, ensuring that the genetic variability necessary for adaptation purposes is maintained.

Basic information on individual breeds or types and on genetic parameters (heritabilities, correlations and genotype x environment interactions), important for developing relevant and sound breeding strategies is still lacking due to the limited capacity of national research institutions to do research.

This paper attempts to review the relevance and application of conventional methods in beef cattle breeding in the tropics. Detailed information on the tropical environment and production systems have been presented before by several authors.

**BREED EVALUATION AND CHARACTERIZATION**

Genetic variation present within and among tropical beef breeds provides the opportunity to develop more comprehensive programs that can economically optimize production under a range of environments and production systems in the tropics. However, identification, evaluation and characterization of these breeds, which are important pre-requisites, still lag behind because of the large costs involved and the length of time required for evaluating cattle. Although much work is being carried out presently to address this problem, as reported by Peters and Thorpe (1988), the majority of the populations, particularly in Africa, have not yet been defined in terms of production characteristics and the environment. Hence it is not yet clear whether there are any significant genetic differences between some of these populations, that could be exploited to improve productivity. Nonetheless, it is certain that each of these populations or sub-populations has a role in the food production system. Determination of genetic distances among some of the populations may be useful, the developments in biochemical genetics may in future be able to provide information on DNA sequences that can be used to measure these distances.

Because of major differences in beef production systems in the tropics, it is important that genotypes and breeding strategies be evaluated both on-station and in the field (i.e., on-farm) before recommendations are made to beef cattle producers, particularly in extensive systems.
Although the cost of carrying out evaluations will be high, the benefits in the long run may be worthwhile, since more efficient breeding strategies can be developed to optimize production under more sustainable basis. Field trials involving farmers need not be elaborate, but just sufficient to provide the crucial information necessary to complement on-station work. Breed evaluation and characterization work is carried out mainly by government institutions on-station. The information obtained, though useful in providing basic comparative production data for different genotypes, is to a large extent applicable only to improved ranching systems, whilst the majority of the beef cattle are reared under traditional extensive systems. Peters et al. (1988) have nonetheless indicated that on-farm livestock performance recording in Africa has increased steadily over the past decade. Indeed, a number of non-government organizations (NGO's) are involved in development programmes which, while not essentially research oriented, provide valuable on-farm breed performance information.

The information obtained from most of the evaluations is limited in coverage, and therefore does not allow proper and sufficient comparisons to be made across genotypes and environments. Trail (1985) noted that only 21% of the publications in Africa contain comparative information on two or three breeds and very few had enough information on different traits to allow complete characterization of the breeds. de Vaccaro, Quijandria and Li Pun (1988) also observed the same problem in Latin America, 61% of the publications reported on only one trait.

Breed values on heritability and genetic correlations for beef traits and information on genetic control of adaptation (so important in the tropics), in particular, heat tolerance, disease and parasite resistance, are necessary for developing relevant breed improvement programs. Very few data on these genetic parameters are available in tropical countries (Tewolde, 1988; Tawonezvi, Brownlee and Ward, 1986). Most of the data were obtained from experiments with short duration and or using small animal numbers, these data are therefore characterized by large sampling errors which limit their usefulness. Information on genetic components such as additive, dominance and interaction effects, important in designing effective crossbreeding systems and cross-combinations is also scarce. Very few publications from research projects present these data (Trail, Gregory, Marples and Kakonge, 1985), because the resources for research in beef cattle breeding cannot support the use of elaborate experimental designs necessary for the estimation of these components.

While some information on breed productivity levels, genetic parameters and genetic components for beef traits can be obtained from the national research systems, it is hoped that the rapid advances made in developed countries in the fields of molecular cytogenetics of cattle and genetic engineering will in future offer better opportunities to look more closely at the genetic aspects of heat tolerance, disease and parasite resistance and other adaptation characters.

The advantage of utilizing regional reference breeds to facilitate exchange of cattle germplasm for genetic improvement programs and to provide a standard for comparisons has been shown (FAO), even though little has been done to make use of such a facility. Evaluation programs have included some common breeds within the regions, which could
possibly be used for this purpose, these include the Africander and Brahman in Southern Africa, the Boran in East Africa and the Criollo and Brahman in Latin America.

Despite the well-intended efforts of most national governments to raise herd productivity levels through, among other things, multiplication and distribution of "improved" bulls, more often, techniques and facilities for performance recording and estimation of breeding values are not sufficiently developed and in some cases are non-existent. Genetic progress in the national herd is reduced because of inappropriate methods used for selecting sires. Development of appropriate techniques for performance recording and evaluation of potential sires on-farm are important and should be an integral part of the breeding program. Presently, a computer program for on-farm performance recording of livestock which has a beef cattle component is available from the International Livestock Center for Africa (ILCA) for use in Africa. Attempts at beef cattle performance recording in Latin America have worked well despite problems faced in extensive production systems (Plasse, 1988a). Only a few advanced countries in the tropics (e.g., Australia, South Africa and Zimbabwe) have well organized performance testing schemes for beef cattle. These provide information to breeders' societies for continued breed improvement programs. In the less developed tropical countries, performance recording can be more beneficial when used in selected nucleus herds intended to supply bulls of known genetic merit to the more extensive commercial producer. It is important however that the environment under which the bulls are produced does not differ significantly from that of the commercial producer.

This limited but important information obtained from research and field observations have led to major changes in breeding policies and strategies in the tropics.

**GENOTYPE x ENVIRONMENT INTERACTIONS**

It is highly desirable when designing breed improvement programs to be able to make a prior estimate of expected genetic change. However, because of the diverse and extreme nature of tropical production systems, significant genotype x environment (GxE) interactions are very common and cannot be ignored. Because of these interactions, the amount of heterosis, degree of crossbred differences and performance of selected or newly developed populations often vary with the environment. Their presence may cause over estimation of possible genetic progress which would lead to implementation of improvement projects when the potential for making progress is quite low.

Differences observed in percent heterosis due to variations in the environment have been reported in several studies (Thorpe and Cruickshank, 1981; Barlow, Hearshaw and Hennessey, 1985; Hohenboken, 1985; Hertzel, 1985). Quite often average heterosis values are used to predict performance of crosses, but because the overall mean performance of genotypes distributed over a range of environments is independent of the GxE interactions, as shown by Mather and Jenkins (1971), these average values do not predict accurately the performance of crosses for specific environments. Also genetic gain made through selection in one production environment may not necessarily be effective in the other, even though climatic conditions may generally be the same. This has been observed in several studies.
involving the Africander breed of cattle in Botswana, Mozambique, South Africa, Zambia and Zimbabwe (APRU, 1980; Dlodlo and Ward, 1987; Thorpe et al., 1981; Lethola-Setshwaelo, 1988). It is therefore necessary that breed selection and development programs be executed in an environment similar to the one in which the resultant population is expected to perform.

The implications of these interactions also make questionable the expected contribution of nucleus herds in tropical areas, where the majority if not all of these herds are kept under improved ranch systems. Evaluation of sires through progeny test should also be conducted under extensive systems.

The ideal situation would be to decide on the range of environments that one would like to breed for and develop genotypes suitable for those environments.

BREEDING STRATEGIES

Crossbreeding

Even though the limitations of breeding systems which utilize temperate breeds in the tropical lowlands have long been recognized (Phillips, 1949), the move from national and international policies which promote breed replacement has been quite slow. While it is acknowledged that crossbreeding does allow exploitation of both heterotic and additive breed effects to improve productivity in beef cattle, important considerations in the tropics are to maintain the right genetic balance for adaptation and a favorable cost/return ratio.

Reports from breeding programs have highlighted increases in performance of crosses between Bos taurus and Bos indicus cattle and between some of the different types of the Bos indicus group, e.g., Zebu x Sanga (Sacker, Trail and Fisher, 1971; Plasse, 1974; Peters and Horst, 1979; APRU, 1980; Trail, Gregory, Marples and Kakonge, 1985; Gregory, Trail, Marples and Kakonge, 1985). These benefits have been attributed largely to heterosis and complimentarity between the breeds, taking advantage of the additive gene effects of the large beef breeds for growth when the dam genotype is well adapted to the environment. In tropical areas, there is always need to maintain an optimum contribution of the Bos indicus breed(s) for purposes of adaptation. The crossbreeding system should then ensure that the proportion of genes contributed by the temperate breed(s) is not at a level that will compromise adaptation. At the same time, the contribution of the Bos indicus should be no more than it is enough to confer adaptability otherwise the production potential would be reduced. The proportion of genes of each type that should be maintained depends on the specific environment and production system, Plasse (1988b) recommended 50% as the level suitable for the Latin American tropics. A more reliable way for assessing this would be to look at total productivity or efficiency of the different crossing systems in economic terms.

Different methods of crossbreeding are available for use in the tropics. The choice depends on the practicability of the method, given the production system and the economics, the best method being the one that gives the highest return to investment. Lack of management
capabilities and the necessary infrastructure required to undertake complex crossbreeding programs in extensive traditional systems limit their use. Even though it is easier in terms of availability of facilities and expertise, for a commercial producer in the tropics to operate these complex programs, careful consideration is important to ensure that possible benefits of improved biological efficiency are not cancelled by large costs of operating the breeding program. The most common and simplest crossbreeding system practiced in the tropics even by the small traditional farmer is the two-way crossing. The benefits of this system in ranching situations have been appreciable. However, the problems in an extensive production system, are lack of control of breeding (which results in indiscriminate crossbreeding in the open rangelands) and appropriate choice of sire breeds. In extensive conditions, improved tropical breeds (e.g., Brahman and Boran) and composites with Bos indicus contribution (e.g., Santa Gertrudis and Bonsmara) are most appropriate since the crosses retain the adaptation even when the environmental conditions become most severe such as, during drought periods. These breeds are now being used increasingly in tropical Africa for this purpose.

Rotational crossbreeding methods are applicable only in large commercial ranching systems where facilities and management are not limiting factors, and such methods have only been practiced on a very limited scale in the tropics. Peters, Kleinheisterkamp, Horst and Weniger (1980) indicated that the two-breed rotations are the most appropriate since no additional advantages are gained in three-breed rotations. However, the wide fluctuations in the additive genetic composition between generations, associated with rotational systems pose a problem in maintaining a balance between the genotype and the environment, since in some generations the Bos indicus contribution may fall as low as 14% as is the case with three-breed rotations (Hohenboken, 1985). Plasse (1988b) reported that a two breed rotation of the Criollo and Brahman in Venezuela had to be discontinued because of low performance in generations with high Criollo contribution; 5/8 and 3/4.

The advantages of using crossbred cows to make optimum use of heterotic effects in fertility and maternal components, can not be sufficiently exploited in the more extensive traditional systems as in ranching. Because of the increase in cow body size and a high potential for milk production, overall requirements for feed are significantly increased relative to the scarce feed resources and low nutritional value of tropical pastures. The large mature size of the crossbred cow is a disadvantage as far as liveweight maintenance and thus its association with reproduction are concerned. Although it may be true that there is some degree of heterosis for adaptation and that heterosis is highest in marginal production systems, observations in Botswana have shown that crossbred females of the Bos taurus type used for breeding purposes under a marginal production environment are characterized by low reproductive rates when compared to the local Tswana cows. Plasse (1988b) also reported low reproductive rates for F1 European x Brahman cows under low nutritional level in extensive production. But preliminary results indicated a slight advantage of these crossbreds over the Brahman when kept under moderate pastures. This low performance was attributed to higher priority given by F1 cows to rearing their calves than to reproduction when the environment is stressful. Feed supplementation during stressful periods (e.g. dry season lactations) then becomes necessary. However, work done in Botswana on supplementation of beef cows stressed by lactation during the dry period, indicated that unless cheaper and locally available feed supplements are found, the benefits achieved through improvements in
reproduction are not large enough to justify the high cost of the supplement (APRU, 1978).

Potential for selection.

Estimates of genetic parameters are necessary to determine as to whether or not selection within the local breeds is a viable option and also for designing the selection programs. This information however is lacking in tropical areas as indicated earlier. Figures from the few reports that are available, have indicated that there is possibly enough genetic variation within some of the cattle populations in the tropics, to make selection effective (Tewolde, 1988; Tawonezvi, 1986). Results obtained from breed evaluation work showing the high production potential for some of the indigenous beef cattle breeds, have also generated the large interest today to substantially improve further the potential of these breeds through selection.

There are currently several selection programs going on in Africa to improve indigenous cattle breeds for beef production (e.g., in Botswana, South Africa, Zambia, Senegal, Ivory Coast and several other countries in West and East Africa). Even though it is well recognized that the population size needs to be sufficiently large, especially when selection is done in stressful environments, such as in the tropics where effects of inbreeding are more pronounced (Kelles and Brinks 1978), the majority of selection herds are very small, about 250 breeding cows and 8 sires on average (effective population size 31 and rate of inbreeding 1.6% per generation). These herds are therefore more vulnerable to inbreeding depression due to the cumulative effects of drift and the selection intensity will also low.

As indicated in literature reports, most beef cattle breeds in the tropics are of a small mature size, a result of natural synchronization of the genotypes with their environment to ensure perpetuation of these genotypes. When selecting these breeds to increase growth rate (hence large mature size) and reproduction, it is possible that a point will be reached when further increases in growth rate and thus mature weight may not be desirable, even though the amount of genetic variation present is such that further genetic progress could still be made. A reduction in reproductive efficiency will be most likely when a certain optimum mature size is exceeded. This assumes that some plateau will be reached at a certain mature weight when the environment can no longer support further increases in weight. The plateau is expected to be different from that observed when genetic variation is exhausted, since the point at which it occurs may differ from one environment to another, and would be highest in favorable environments. It is important then that selection be done in an environment similar to the one in which the animals are expected to perform, in order to achieve as much genetic progress as possible and also that adaptation is not compromised.

Although selection programs in the tropics are plagued by a number of problems such as lack of infrastructure, some of the few attempts in the past have been successful in achieving appreciable levels of genetic progress in the traits under selection. Breeds such as the Tuli and Boran (Trail, 1985) have been improved through selection within the indigenous types. Tewolde (1988) and Tawonezvi et.al., (1986) have also reported substantial genetic progress in selection for beef traits respectively, in the Criollo and Nkone cattle. Most of the current selection programs mentioned above are executed by government institutions. The expected
impact of these herds in raising the national herd performance level (assuming selection is effective) is very limited because of the small number of animals. The major contribution of the institutional herds may then be in ensuring that the breeds are conserved and also to create awareness in farmers of the potentials of the breeds. Selection within nucleus herds belonging to farmers therefore offers a better opportunity for improving the national herd average in traits of economic importance.

Potential for composite (synthetic) populations

While the potential of most tropical beef breeds is too low to meet the required production levels, the majority of beef cattle producers in the tropics can not maintain well organized, self sustained crossbreeding programs. The possibility of using composite populations, which combine adaptational characteristics of the indigenous breeds with the high genetic potential of exotic breeds to increase beef production efficiency, has been addressed by several authors before and the concepts are well developed. Composite populations as indicated earlier in the text are extensively used in the tropics.

Even though the problems of small population and inbreeding depression can be avoided where resources permit, the risk involved in breed development are somewhat higher than those in a selection program. The very high performance level observed during the initial generations in the composite population, as a result of the high level of heterozygosity and thus heterosis, is partly lost during the development process. Results from a composite breed development program in Botswana have shown a 16% advantage of generation two productivity over the local Tswana cattle (APRU, 1988). Plasse (1988b) also reported a 10% advantage of the composite population over an elite zebu herd in Generation2/Generation3 in total productivity and 19% and 13% advantage in pregnancy rates in the first year of two other composite populations in Venezuela. It is only hoped that at least one half of this superiority will be retained in the advanced generations, otherwise the investments made will not be justified. Because of these initial gains, the programs may continue for several generations, before it is realized that the population does not have any significant advantage over existing breeds. At that point, a lot of time and money will have been spent on the program. The possibility of improving such a population through selection in later generations when the numbers are sufficient, though comforting, is also time consuming and expensive. It is important to note that in developing countries, such capital intensive and long term projects are viewed more as developmental than experimental. Resources to undertake long term breeding programs are scarce and therefore the competition for those resources is quite high. It is the responsibility of beef cattle breeders to choose breeding strategies that have the highest chance of success. Ideally, a breed development program should go hand in hand with selection of indigenous breed(s), so that the programs provide a backup for one another.

BIOTECHNOLOGY IN BEEF CATTLE IMPROVEMENT PROGRAMS

The rapidly advancing fields of molecular genetics and reproductive biology in the developed countries are opening up further opportunities to enhance genetic improvement programs in
the tropics. Technologies such as artificial insemination and synchronization of oestrus are now being extensively used to facilitate breed improvement programs. Of specific interest to the animal breeder in the tropics today is the development of multiple ovulation and embryo transfer (MOET) techniques and recombinant DNA - technology for gene mapping in cattle. Although MOET is now used commercially in the developed world, the technique is expensive and therefore its use in commercial production in the tropics is still very limited. However, the potential application of this technology in facilitating long term genetic improvement programs such as selection and breed development is enormous. Because of the low reproduction in tropical cattle, a lot of time is spent accumulating the number of breeding females required for the following generation. For instance, to maintain a breeding herd of 400 females per generation requires at least three successive breeding seasons (assuming the calving rate and survival to breeding age respectively are 70% and 82%) to produce enough females per generation (as has been the experience in Botswana). MOET can therefore be used to multiply the numbers for breeding (reducing the time spent), increase the intensity of selection and also multiply populations already improved for distribution purposes. The argument advanced previously against selection in the tropics (i.e., length of time involved) will then lose weight.

Although breeding for disease resistance can still be done using conventional methods, advances being made today in mapping cattle genes and developing composite gene maps (Womack and Moll, 1986; Womack, 1987.) may in future make it possible to select for disease resistance in tropical livestock using genetic markers. A genetic linkage map for cattle is already being developed with the prospect of using it to aid research in the genetics of trypanotolerance (Trail and D’leteren, 1989.). Although the research still has a long way to go, it will be a great contribution to livestock breeding in the tropics where adaptation and resistance or tolerance to some endemic diseases are of paramount importance.

REFERENCES


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