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Evaluation of Large Ruminants for the Tropics

Proceedings of an International Workshop held at CSIRO, Rockhampton, Queensland, Australia, 19-23 March 1984

Editor: J.W. Copland

Contents

Foreword

IN developing countries livestock and livestock products are a vital sector of the rural economy because of their contribution to draught power, both on the farm and for market transport, the national diet and export earnings.

National governments, almost without exception, provide support via research, health control, and extension services, which unfortunately are limited by the resources of skilled manpower and funds. There are national policies to increase livestock productivity by genetic methods and through environmental improvements (e.g. better nutritional and disease control).

Well-planned, comparative breed evaluation studies are a starting point for planning increases in productivity because they define not only the production possibilities of existing genotypes in existing management systems, but also their relative strengths and weaknesses in the ability to respond to environmental changes.

ACIAR was pleased to sponsor the Workshop on Evaluation of Large Ruminants for the Tropics at the CSIRO Tropical Cattle Research Centre, Rockhampton, and acknowledges the importance of bringing together Australian and overseas scientists with interests in breed evaluation and livestock improvement to:

(1) Identify the needs, priorities, and specific problems of large ruminant production in developing countries and areas of possible cooperative research between Australian and overseas institutions.

(2) Collate existing information that seeks to characterize specific breeds on a comparative basis in terms of their overall productivity, specific productive and adaptive traits, and the influence of various environmental factors on productivity.

(3) Formulate requirements and procedures for more effective evaluation of indigenous and introduced large ruminant resources.

(4) Advise ACIAR of their findings.

This publication is the result of the Workshop and includes the papers presented by scientists from Australia, Africa, South-east Asia, and the South Pacific, and the Conclusions and Recommendations.

I would like to thank Dr. John Vercoe and the staff of the CSIRO Division of Tropical Animal Science for their assistance in holding the Workshop, and H. Greig Turner and J.V. Mertin for their parts in preparing the manuscript for publication.

J.R. McWilliam
Director
ACIAR

Part 1

Current Status and Needs of Developing Countries

Buffalo and Cattle

Current Status of Buffalo Breeding Programs in Malaysia

S. Jalaludin*

THE domesticated buffalo (*Bubalus bubalis*) population in Malaysia is nearly 200 000 head and is represented mostly by the swamp variety. The Murrah buffalo numbers less than 3000 head. Apart from its wallowing habits, draught, and meat producing ability, the swamp buffalo is further differentiated genetically by having 48 chromosomes instead of 50 as found in the Murrah, the dairy type of buffalo.

For many centuries, the buffalo has played a significant role in the overall growth of the Malaysian agricultural industry particularly in providing draught power for the cultivation of rice. Although its usefulness in the rice growing sector of agriculture is fast declining due to increased farm mechanization, the buffalo still contributes about half of the local meat production and strangely is gaining importance as a draught animal to transport fruits during harvest in the oil palm estates. This is because the difficult terrain in most estates prohibits the use of machinery. Oil palm is one of Malaysia's export items and it has displaced rubber as the country's foremost income earner.

Very little milk is produced by the swamp buffalo but the potential is much greater with the Murrah. However there have been cases where selected swamp buffalo cows are milked. Despite the importance of buffalo in tropical agriculture, especially in rice cultivation, there has been a steady decline (about 10%) in the population in Malaysia over the past 40 years, mainly the consequence of neglect. The attitudes towards buffalo keeping have changed somewhat as its potential is gradually realized. However, present research efforts are considered inadequate (at least in Malaysia) to prevent a continuous slide in the population, let alone reverse the trend. There is certainly a need to consolidate ongoing research activities and at the same time expand into new areas that are considered important. This paper presents the status of buffalo research in Malaysia and outlines the research approach that is necessary to exploit the full potential of buffaloes.

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General Characteristics

The swamp buffalo has adapted well to the hot humid regions of the tropics where environmental conditions are severe. Under the Malaysian environment, adult male and female buffaloes could weigh as much as 800 and 500 kg respectively, with an average daily gain ranging from 0.26-0.96 kg (Jainudeen 1983).

Female puberty occurs at 21-36 months, with an average calving interval of about 532 days recorded on the Universiti Pertanian Malaysia farm. Histological evidence indicates that male puberty (spermatogenesis) occurs at approximately 16 months (Nordin 1983) but spermatozoa are seen in the ejaculate only at 24 months of age. The oestrous cycle is estimated to be 21 days and oestrus usually lasts for 18-21 h with ovulation occurring 15-18 h after oestrus ends (Jainudeen 1977). In the buffalo, overt signs of oestrus are not very obvious as in cattle. Acceptance of the male, which usually occurs at night, is the main indication of oestrus.

Buffaloes have limited sweat glands and wallowing is necessary to maintain body temperature equilibrium. According to Kassim and Baharin (1979) wallowing takes place between 10 and 20h.

Haematological parameters for swamp buffaloes were determined by Sulong *et al.* (1980) and the values obtained were: total erythrocyte count (8.8 million cells/μl); haemoglobin concentration (13.4 g/d); packed cell volume (39.2%), and total leucocyte count (10.7 thousand cells/μl). In the case of total erythrocyte count, it was higher than that recorded in river buffaloes.

Buffalo meat sold in the market is of poor quality because most animals are slaughtered at the end of their working life. However, when buffaloes and F_1 Hereford crosses with local cattle at comparable ages and body weights kept under similar conditions were compared, there was little difference in the carcass characteristics except that less fat was present in the buffalo carcass (Hilmi and Vidvadaran 1980).

Water buffaloes are traditional draught animals, used extensively in rice cultivation for ploughing, harrowing, and threshing. It has been estimated (Kamonpatana and Walker 1969) that a buffalo takes about 13 h to prepare 0.2 ha of a rice plot ready for cultivation. In a day, a buffalo may be put to work for as long as 7 h.

Most buffaloes are located in areas where cultivated forage crops and pastures are limited. The bulk of their diets consists of agro-industrial by-products, which are generally of low feeding value. Even under such situations, buffaloes have been shown to perform reasonably well; this capacity is one of their important traits.

Physiology

Extreme tropical weather causes stressful effects on the animal. Very little is known on the environmental physiology of the buffalo, particularly the swamp variety. Earlier studies using river buffaloes did show that physiologically they differ from cattle. The values obtained for body temperature, respiration rate, and pulse rate were lower than for cattle. Buffaloes also have thicker skin, and the limited number of sweat glands leads to the need to wallow. Such behaviour is not acceptable because fields are damaged by the creation of wallowing pits; it is an inhibiting factor for large-scale commercial ranching of buffaloes.

There is a need to understand the thermoregulatory characteristics of the buffalo in order to determine the significance of wallowing so that appropriate management practices both under grazing and confined situations can be provided to maximize production.

Genetic Improvement

Great genetic variability exists between buffaloes in Malaysia as they have never been selected or subjected to any kind of breeding program. Certain poor traits are exhibited. Genetic improvement is necessary to enhance the complementary roles of swamp buffaloes in a mixed agricultural system practised by the majority of small-scale farmers.

There are two courses of action that can be taken in genetic evaluation and improvement of swamp buffaloes: (a) selection within strains, and (b) crossbreeding swamp buffaloes with river buffaloes. The choice of the method will depend to some extent on the traits desired and prevailing farming systems.

Record-keeping in the swamp buffalo population is virtually non-existent. The principal reason for this neglect is that, despite the importance of the swamp buffalo in the national economy, the infrastructure for its improvement is weak in most instances. Except for two large institutional buffalo farms, the majority are kept in small numbers throughout the country, and this makes any form of organization very difficult.

Nevertheless, it is realized that selection within strains could lead to a steady genetic improvement in traits such as draught and meat production, because of the moderate to high heritabilities of growth rate and body weight, and the possibility that traits can be measured in the breeding animals of both sexes (Mahadevan 1983).

Performance recording is a basic requirement for genetic improvement but in a situation like that in Malaysia where such an exercise seems ambitious, it will suffice for the moment if efforts can be concentrated towards the evaluation of sires. This work can be easily undertaken using the present facilities in the buffalo farms at Universiti Pertanian Malaysia and MARDI. Bulls which have been screened and selected can be kept for semen production to be used in a national AI program. The idea of progeny testing should not be completely abandoned but can be introduced gradually with the build-up of expertise and facilities. However, the difficulty of organizing progeny testing should not be underestimated, even when infrastructures are upgraded.

In most Asian countries the indigenous swamp buffaloes are being upgraded by crossbreeding with imported river stock (e.g. Murrah) so as to reap the advantages of heterosis. The F_1 hybrid (Murrah x Swamp) has a greater growth rate and milking capacity than the local swamp type and carries a chromosome complement of 49 (Bongso and Jainudeen 1979). It was demonstrated that a chromosome re-arrangement (4/9 tandem fusion) in the hybrid and swamp types was responsible for the evolutionary dichotomy of this species (Bongso and Hilmi 1982). Since further breeding of the hybrids usually involves *inter se* matings between F_1 or backcrossing of F_1 females to Murrah male stock, the implications of the 49 chromosome complement for fertility were investigated. Reproductive fitness has been shown to be affected in other hybrids possessing chromosome complements different from the parental types, such as the mule, hinny, cattalo, horse-donkey hybrid, and the Indian x Chinese muntjac.

Meiotic preparations from testicular biopsies from buffaloes carrying 49 chromosomes revealed spermatogonial metaphases, pachytene, diplotene, diakinesis, first and second meiotic metaphases and spermatozoa. Chromosome sets ranging from 22-26 (most frequent 24 and 25) with many cells carrying univalent, bivalent, and multivalent configurations were observed. Histological examination of the hybrid testis revealed a large proportion of degenerating spermatocytes and abnormal spermatids in the process of spermiogenesis, suggesting that the various synaptic associations leading to unbalanced gametes may be responsible for the degenerating germ cells in the hybrids. It was suggested that the unbalanced meiotic products will probably lead to selection against such spermatozoa or early embryos after fertilization. Due to reproductive wastage in the hybrids the fertility of such animals having 49 chromosomes may be reduced (Bongso *et al.* 1983).

Studies are thus required to karyotype, and evaluate accurate field reproductive data of, a large sample of such hybrids (49 chromosomes) and compare such data with pure swamp animals, so as to find out if there is a real reduction in fertility and if so, by how much. If a significant reduction in fertility is obtained, a new breeding policy for the buffalo for Asia may need to be formulated.

Preliminary studies in Malaysia also revealed that two back cross (F_1 female x Murrah male) types of animals were obtained, with 49 and 50 chromosomes (Bongso and Hilmi 1982). The sample size investigated was small. Therefore, further studies are necessary on a larger sample of backcrosses so as to elucidate the exact frequencies of animals with 49 and 50 chromosomes. The reproductive efficiency of buffaloes in Asia is generally regarded as being lower than that of other domestic animals. It is thus important to ensure that this is not exacerbated by a crossbreeding program that may cause additional burden to the already low reproductive ability of the species.

The use of the F_1 as a terminal cross is beneficial because of the heterosis exhibited. The effects of further breeding as related to reproductive fitness needs to be investigated. It is also desirable to study the degree of hybrid vigour in the crosses.

The establishment of a data bank for swamp buffaloes would be complementary to other processes of genetic improvement. It has been suggested (Mahadevan 1983) that the characteristics described in the data bank should include all the production traits of the animals concerned, in addition to the distinguishing physical features of the breed, strain, or cross. It is also recommended that separate values be given for genetic and phenotypic traits and that where possible information be included on newly investigated characteristics, such as blood and biochemical traits, karyotype, and immunological characteristics.

Preparations are currently underway to establish a data bank in Malaysia, to include swamp buffaloes. For the time being, data compilation will be entirely based on already published work. The project is one of the two data banks that FAO is financing.

Reproduction

Much of our knowledge on buffalo reproduction is based on studies in cattle. While this information has proved highly relevant to the buffalo, indiscriminate extrapolation of such findings to buffaloes must be viewed with extreme caution.

Reproduction has received greater attention in the river buffalo than the swamp buffalo. Perhaps this is because of the importance of regular reproduction for the initiation of lactation in the dairy buffalo. On the contrary, a similar demand on reproduction does not exist for the working swamp buffalo. Gaps in our knowledge of buffalo reproduction become evident when the meat-producing potential is to be exploited.

Certain phases of the reproductive process may be manipulated to improve the reproductive performance of the swamp buffalo. Artificial insemination (AI) is one method by which extensive breeding of buffaloes is possible with a few proven buffalo bulls. However, AI in buffaloes has lagged behind that for other species primarily due to a lack of suitable extenders for freezing buffalo semen. The semen of the swamp buffalo has now been successfully frozen and satisfactory conception rates have been achieved. The semen of sires could be frozen and stored until they are proven.

One of the major constraints in the application of artificial insemination as a method for rapid genetic improvement in the swamp buffalo is the difficulty of oestrus detection. Techniques have been developed using synthetic analogues of prostaglandin 2a (PGF_2alpha) to induce synchronized oestrus and permit insemination of females at fixed times. Fixed time insemination is a valuable method for upgrading buffaloes at the village level.

Among the advantages of oestrus synchronization are the reduction of errors associated with detection of oestrus and the concentration of calvings, with possible increases in calf crop arising through improved herd management. Postpartum anoestrus effects 30-40% of swamp buffaloes. A swamp buffalo produces two calves every three years. Using several techniques for the diagnosis of ovarian function (progesterone assays, rectal palpation, and laparoscopy) we have established that the long calving intervals in the swamp buffalo are due to a failure in the resumption of ovarian activity. Body condition, suckling, and parity are known to influence the resumption of ovarian activity. A reduction in the calving interval necessitates that ovarian activity is initiated early in the postpartum period. A management strategy for reducing the incidence of postpartum anoestrus has been established. It involves the use of a progesterone-releasing intravaginal device (PRID) and temporary calf removal for 72h. Most animals are detected in oestrus within 48-72h and a high percentage ovulate.

In 1983, studies were initiated on superovulation and non-surgical recovery of embryos. Pregnant mare serum gonadotropin (2000-3000 i.u.) was used to induce superovulation. The ovarian response ranged from 3-8 ovulations per treatment. Non-surgical techniques have also been developed to recover embryos from the uterus via the cervix.

The availability of frozen semen and the concept of fixed time insemination have provided us an opportunity to use selected sires extensively and to develop progeny testing schemes. In addition, an AI service will be provided in villages where males for breeding are not readily available.

The development of satisfactory methods for oestrus synchronization, superovulation, and non-surgical recovery of embryos has both scientific and practical uses. Studies are planned to determine the role of viruses in embryonic mortality. Embryos will also be transferred from selected buffaloes to increase the number of progeny from superior females.

Nutritional Requirements and Constraints

The feed resources available to swamp buffaloes consist of poor quality forages from uncultivated land and crop residues such a paddy straw and palm press fibre (a by-product from palm oil milling). These by-products are bulky commodities, usually unpalatable, and contain small amounts of protein. In spite of these properties, crop residues constitute an important feature in tropical animal production where feed resources are a major limiting factor. Expanded livestock farming in Malaysia will no doubt depend on the degree that these residues can be successfully incorporated into the animal's diet.

Quantitatively, there are more than adequate amounts of crop by-products to meet the nutritional needs of the entire ruminant population in Malaysia. The two major nutritional constraints to production are the poor digestibility and limited intake. Against such a background it is not surprising that nutritional research is centred on the treatment of fibrous residues so as to improve their digestibility and nutritive value. The effects of physical and chemical treatment on paddy straw have been widely studied and the results indicate varying degrees of success. In many instances the benefits derived are nullified by the high costs of treatment. This has led to a resurgence of interest in the use of untreated straw by ruminants supplemented with soluble and non-soluble energy and protein.

In many of the past studies utilizing fibrous by-products, cattle were used as experimental animals and the results obtained from such studies cannot be wholly applicable for buffalo nutrition. There are already indications suggesting that buffaloes are more efficient in utilizing by-products (Aznam 1983), although the reasons are not fully known (Table 1). There is obviously a need to study the factors influencing digestibility in the rumen of buffaloes and to compare it with that of cattle. Such knowledge on rumen functions can help to achieve maximization of feed utilization.

Table 1. Comparative dry matter digestion rate (%) of untreated versus treated palm pressed fibre, in cattle and buffalo.

Species	Untreated fibre		Treated fibre	
	24h	48h	24h	48h
Cattle	20.92	27.45	29.96	35.84
Buffalo	28.98	33.04	38.10	39.92

The prospects of buffalo production in Malaysia, even at a commercial level, based on the utilization of palm oil milling by-products such as palm press fibre (PPF), are indeed very good. There is very little use at present of PPF and the amount available annually is in the region of 1.3 million tons. The availability of PPF is expected to increase as the oil palm industry continues to expand. As PPF is produced in large quantity by mills, large-scale buffalo feedlots can be integrated with the oil palm industry.

Palatability may limit the voluntary intake of PPF but spraying molasses (12%) on to dried PPF increases the DM intake to about 2% of body weight.

PPF contains 77.6% cell wall, is highly lignified, and is deficient in phosphorus and copper (Table 2). The digestibility of fibre, determined by suspending samples in nylon bags in the buffalo rumen, varies between 30 and 40%. Chemical treatment with 6% NH_4OH solution at 1:1 (w:v) ratio has improved the digestibility of fibre by only 7%. This increase can be considered as only marginal and, for PPF to be used in practical diets, its digestibility needs to be further improved. Other chemical and/or physical treatments will be studied in order to determine their effectiveness.

Table 2. Chemical composition of palm press fibre on dry matter basis.

DM %	CP %	EE %	HMC %	C %	Lgn %	Ash %	Ca %	P %	Mg %	Cu mg/g
70.6	6.2	14.7	18.2	37.1	21.0	2.9	0.3	0.1	0.1	3.6

DM = dry matter; EE = Energy Equivalent; HMC = hemicellulose; C = cellulose; Lgn = lignin

Disease Status

Information relating to diseases of swamp buffaloes is scarce. Buffaloes probably are as susceptible as cattle to most infections but they do however respond differently. Buffaloes seem to be peculiarly sensitive to a few cattle diseases and resistant to a few others. The observed differences in disease reaction between buffaloes and cattle are not fully understood.

Haemorrhagic septicaemia (HS) is endemic in Malaysia and causes heavy losses particularly among buffaloes. Routine vaccinations on all buffaloes above 6 months of age help to prevent new outbreaks of HS. The incidence of other major diseases found to be prevalent in the local buffalo population are leptospirosis (33%), neonatal diarrhoea in calves (15%), Johne's disease (20%), infectious bovine rhinotracheitis (65%), and nearly 98% of all buffaloes examined had one or more species of bacteria in their cervico-vaginal mucus. Some of the bacteria isolated are pathogenic and can cause repeat breeding and infertility. Bovine malignant catarrh (BMC) has also been reported to occur in certain buffalo populations but the extent of infection has not been estimated.

The diseases mentioned have been identified mostly from clinical and post-mortem findings but the causative agents have not been isolated yet. Preliminary studies at UPM succeeded in identifying the IBR virus, which has since been characterized (Saw 1983). The organism responsible for causing bovine viral diarrhoea has been isolated and is now undergoing study. The epidemiological features and the effects of these diseases on economic losses are little known.

Investigations into the incidence of parasitic diseases in the buffalo are lacking. The most pathogenic parasites known to affect buffalo calves below 3 months of age are coccidia and strongyles that cause an enteritis and gastroenteritis, respectively. Cases of surra in the buffalo have been reported but the extent of the harm that it may cause to the animal has yet to be studied.

Biotechnology

Besides the high cost of operations, genetic gains from selection studies and progeny testing are indeed time consuming. It is thus necessary to consider alternative research approaches in the field of genetics that could bring about dramatic results more quickly. In this respect genetic engineering has become important. Advances in recombinant DNA technology, monoclonal antibody production, tissue culture and protoplast fusion are being energetically exploited. Tools in genetic engineering have been used for the location of genes and amino acid sequences of proteins. It is also feasible to construct entirely new genes and to modify the known ones. So far, the principal practical results have been obtained with genetic manipulation of micro-organisms, notably *E. coli.* The genomes of other prokaryotypes are now being altered using an increasing array of biotechniques.

Genetic engineering should not be considered as very sophisticated research that is beyond the scope of developing nations. While simple field operations can be a problem mainly due to attitudes of farmers and workers, it would not be difficult to achieve results in the laboratory. Some of the possible areas of application of genetic engineering methodology in the water buffalo are as follows:

1. Gene Mapping of Buffalo Chromosomes

Somatic cell genetic techniques, in particular somatic cell hybrids, have been exploited successfully for the assignment of gene loci to individual chromosomes and chromosome regions. This has been successfully carried out on the human karyotype and could be used successfully for buffalo breeding.

2. Synthetic Vaccines

In classical vaccine production, (a) the source of the natural antigen can be dangerous and/or impossible to prepare in sufficient amounts, and (b) cross-reaction with host tissues can also occur. Thus, artificial preparations as substitutes for native antigenic determinants using recombinant DNA technology and genetic engineering could be used as vaccines against the major diseases of water buffaloes such as HS, foot and mouth, and other diseases reducing the productivity of this species.

3. Microbial Production

Recent development of cell fusion and recombinant DNA technology (genetic engineering) has made possible genetic recombination between different species of microbes and has helped increase their biosynthesizing activity by increasing the gene copy number or improving the micro-organism in relation to the substrate and environmental conditions. Similar research directed at the rumen microflora of water buffaloes could result in an improvement of this micro-environment and subsequent increased productivity through better conversion of feedstuffs.

4. Benefiting from Advantageous Traits

The most spectacular results could be obtained by using newly fertilized buffalo eggs. Foreign genes might be injected into the male nucleus and incorporated into the chromosomes, leading to a life-time and heritable expression of their effects in the buffalo. Traits carrying several advantages could thus be exploited using this method.

Conclusions

Very few studies have been conducted on the breeding of the swamp buffalo. Current research is concentrated mostly on nutrition, reproduction, and cytogenetics. Experimental results have demonstrated such positive traits in the buffaloes as (a) resistance to disease, (b) tolerance to extreme weather conditions, (c) draught power, (d) high growth response, (e) good carcass quality, and (f) efficient conversion of low quality feeds. These traits could be further enhanced through upgrading processes.

There are many practical problems associated with organizing effective selection programs and pregnancy testing when existing infrastructures are weak. In a situation where success is more assured in the laboratory than in the field, the choices of genetic research that need to be pursued have to be carefully selected. Under such conditions it is clear that genetic studies in the buffalo should include (a) screening of bulls for semen production to be used in a national AI program, (b) karyotyping of Murrah × Swamp F_1 hybrids for reproductive fitness where cross breeding programs are under way, (c) determination of hybrid vigour in the crosses, and (d) initiation of biotechnology research to facilitate studies on gene mapping for more rapid genetic gains.

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Strengthening Carabao Research in the Philippines

A.N. Eusebio*

THE carabao is one of the most important but neglected species of farm animals in the Philippines. This is reflected by the little attention given this animal by our animal scientists, planners, and administrators till recently, as shown by the very small proportion of research and development efforts that have been done to improve its productivity, compared with all aspects of poultry, swine, and cattle production (PCARR 1981). It is no wonder that our carabao still remains unimproved and a relatively inefficient draught animal as well as a poor producer of human food in the form of meat and milk commodities.

The recognition of the great economic potential of the carabao in the agricultural sector, especially for countryside development, prompted the Philippine Council for Agriculture and Resources Research (PCARR) to separate and create the carabeef commodity from the original beef/carabeef/chevon (goat meat) commodity in 1975. This resulted in the organization of an inter-agency, multidisciplinary national carabeef research team, establishment of the carabao research network, and formulation of a national carabeef commodity research program with identified major researchable priority areas that are relevant to the country's development thrusts, namely: food and nutrition, import substitution, export generation, energy resource management and conservation, and improved socio-economic well-being of the people.

The contribution of the carabao to the national ecomony is principally in terms of draught power for farm tillage and transport, and as a source of meat and milk. It has been reported that about 72% of the total carabao population is used for farm work, especially by the smallholder farmers (BAE 1976). A recent study in four regions in Luzon shows that 77% of the farmers used carabao power in their farming operations (Guzman 1981). A similar study indicates that the majority of farmers in the Visayan regions raised and used carabaos for draught (Subere and Parker 1978).

The serious scarcity of work carabaos is reflected in two reports of PADAP (1978, 1980) based on surveys made at Zamboanga del Sur in Western Mindanao, which indicated a shortage of 28 000 work animals in the region. Obviously, the demand for draught animals would be on the upward trend considering the continued worsening energy crisis and the consequent shift from small-scale farm mechanization to the use of biological power.

Local beef/carabeef production has always been outstripped by demand. Thus, in 1982, the Philippines imported about 7451 m.t. of meat and meat preparations valued at US$17.1 M, (PCARRD 1983). Indications are that importation is inevitable since the projected local supply of beef/carabeef for 1984 is 107 280 m.t. compared with the effective demand of 134 110 m.t.

It may be of interest to note that results of surveys by the Special Studies Division, Ministry of Agriculture (1976-1982) revealed that annual per capita intake of beef/carabeef had declined from 6.1 kg in 1970 to 3.0 kg in 1976 and 2.0 kg in 1982, which may be compared with the per capita nutritional requirement of 4.5 kg recommended by the Food and Nutrition Research Institute of the National Science and Technology Authority.

In the case of the domestic dairy industry, local milk production is meeting only 1% of the total requirement and the balance of 99% is imported. In 1981 for instance, the Philippines imported 92 771 m.t. of milk products in liquid milk equivalent, valued at US$134.86 M. By 1985, demand for milk and milk products is expected to increase to 132 000 m.t. of skim milk powder equivalent. Since consumers' preference is for the cheaper reconstituted or recombined milk, the inexorable laws of economics have operated in favour of importation, with an adverse effect on local fresh milk output. For this reason, without any price incentive paid to producers, efforts to develop the domestic dairy industry would not progress as envisaged in the national dairy development program through the Philippine

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Dairy Corporation. This program aims to achieve a safe degree of self-sufficiency in dairy production by improving the milk production potential of the local cattle and carabaos by crossing with exotic breeds of dairy cattle and riverine buffaloes.

Breeds and Population of Water Buffaloes in the Philippines

Two types of water buffaloes are recognized: the swamp buffalo to which the Philippine carabao belongs, and the river buffalo, which is predominantly the Indian buffalo (*Bubalus bubalis* Linn). These two types differ in various physical characteristics and chromosome number.

The great majority of the buffaloes in the Philippines are native carabaos and only a few hundred are Indian buffaloes and their carabao crosses—mostly of the Murrah and some Nili-Ravi and Kundi breeds. These are scattered notably in Central and Southern Luzon regions and some areas in the Visayas and Mindanao. There are also a few of the Kampuchean breed of buffaloes (and their crosses with carabaos and Murrahs) that are found in the Visayas, mostly in Bohol, but also in certain areas of Mindanao.

In the island of Mindoro located south-west of Luzon there exists about 200 of a wild type of buffalo called Tamarao (*Bubalus mindorensis*), which is noted for its fierceness and has never been domesticated.

The country's total carabao population from January 1, 1976 to 1981 is shown in Table 1. The overall average yearly population growth rate has been only 0.51%. About 99% of the population is maintained by small holder or backyard farmers in units of 1 to a few head, primarily supportive of farming activities. The other 1% is raised in semi-commercial or ranch-type production systems usually in herds of 10-50 head, although herds of 100-200 head are raised in some private and institutional farms.

Table 1 shows that the highest concentration of carabaos is in the Chagayan Valley region with 407 600 head in 1981, followed by Central Luzon and the Ilcos regions with 287 100 and 276 500 head, respectively.

The lowest number of carabaos during the same period was in Western Mindanao with only 158 500 head.

The rate of increase of the carabao population may be attributed to the following factors: (1) indiscriminate slaughter of carabaos despite the existence of a government ban on slaugher of male and female carabaos below seven and 11 years of age, respectively; (2) preference of farmers for big male carabaos, which are generally castrated for farm work; and (3) the disposal for slaughter of significant numbers of pregnant caracows.

One report indicates that 25% of the female carabaos delivered to the abattoirs are pregnant (PCARR 1981). Such a situation is unfortunate and

Table 1. Carabao population by region, 1976-81.

Region	1976	1977	1978	1979	1980	1981	AYGR*
Ilcos	256 640	276 710	279 370	273 390	281 470	276 500	1.57
Cagayan Valley	439 550	477 390	458 580	425 820	432 400	407 600	-1.33
Central Luzon	298 410	300 770	303 400	260 540	281 880	287 100	-0.48
Southern Tagalog	250 980	267 380	275 610	278 590	276 110	265 000	1.16
Bicol	233 390	240 280	252 730	238 140	251 620	249 900	1.47
Western Visayas	280 020	307 410	292 930	281 740	291 050	272 500	6.36
Central Visayas	176 020	176 540	181 420	173 410	173 390	179 900	0.48
Eastern Visayas	180 560	185 580	208 690	193 620	187 470	169 900	0.91
Western Mindanao	147 580	155 820	158 640	171 810	163 560	158 500	1.56
Northern Mindanao	125 450	159 640	151 460	157 200	180 510	173 600	7.38
Southern Mindanao	157 910	173 400	193 080	174 970	168 590	159 500	0.55
Central Mindanao	178 170	176 470	202 810	174 030	182 220	182 600	0.94
Philippines	2 724 680	2 897 390	2 958 720	2 803 260	2 870 270	2 782 600	0.51
Growth rate (%)		6.34	2.12	-5.25	2.39	-3.05	0.51

*Average yearly growth rate (%).
Source: BAI/ B.A.Econ. Survey.

alarming because of its adverse effect on the country's carabao breeding base, which has serious implications for the improvement and development of this species of farm animal.

Importation of Indian Buffaloes

The first introduction of Indian buffaloes was the importation by the Philippine government in 1917 of 57 head, probably of the Kundi or Nili-Ravi breeds. The second importation was made in 1918 consisting of 85 head (Villegas and Sarao 1930).

After World War II, 935 Indian buffaloes, mostly Murrah and some Nili-Ravi and Kundi breeds, were imported into the country as follows:

Year	Male	Female	Young Stock
1947	81	48	16
1950	3	116	—
1953	100	—	—
1955	22	317	153
1966	—	—	98

The breeding of these Indian buffaloes with the Philippine carabaos gave rise to the production of bigger sized, hard-working Indian-Philippine carabao crossbreds and grades for draught and/or milk production by Philippino farmers (Villegas 1968).

In May 1983, some 600 head of Australian water buffaloes were brought into the country, presumably to build up the breeding base. However, these are rather small, weighing on the average 250-300 kg compared with the average liveweight of 250-400 kg of the female and 400-500 kg of the male Philippine carabao.

Breeding Program Policies

There are no established and clear-cut national animal breeding program policies. The specific intent of the importation of Indian buffaloes is to use the exotic germplasm of these animals to improve the draught capacity and milk production of the local carabaos, with the greatest coverage possible, through the livestock dispersal program of the Bureau of Animal Industry (BAI), Ministry of Agriculture.

Unfortunately, most of this exotic germplasm was lost from the recipient institutions, except at the Central Luzon State University (CLSU) where a purebred herd of Murrah buffaloes has been maintained and is now the only source of exotic bulls for dispersal and breeding purposes.

In 1963, the National Artifical Breeding Centre (NABC) was established at the BAI Stock Farm in Alabang, Muntinupa, Rizal, as a joint Dairy Training and Research Institute (DTRI)-UNDP/ FAO Project. NABC handles not only the training of AI technicians for both government and private agencies, but also collection and processing of semen, research, and extension. Records collected from 1977 to 1981 showed a total of 8783 caracows and grades had been artifically bred with frozen/ refrigerated Murrah buffalo semen (Bonifacio 1983). Most of these inseminations were made free of charge for farmer cooperators of the DTRI and BAI milk collection schemes. However, farmers who are not members of these schemes are charged a fee of P6.00 per service. It takes an average of 2.3 inseminations to settle a caracow.

The BAI has also embarked in some areas of Central Luzon on a carabull loan program to farmers who could not be regularly serviced with AI. The problem encountered is the indifference of the Murrah bull to the caracows unless it has been in close association with them for a long time, preferably from calfhood to sexual maturity.

Under the present FAO/UNDP-PHI/78/017 Carabao project, a modified version of the loan bulls scheme has been started in Nueva Ecija by putting up a community night corral. A selected and trained Murrah buffalo bull from the CLSU ranch type carabeef research centre is brought to a village and kept in this corral for a given period of time to service farmers' non-pregnant caracows brought to the corral at night time.

Performance of Carabao and Buffalo

An intensive review of research on the carabeef industry covering the period 1969-78 showed very limited attention given by our researchers to the development and improvement of the carabao. This explains the insignificant progress attained, so far, in exploiting the productive efficiency of this farm animal. The problem areas identified that need priority attention are breeding and reproductive physiology, feed and nutrition for milk and meat production, draught capacity, and socioeconomics of carabao production (PCARR 1981). Some of the more important highlights of studies made on the local performance of the carabao and buffaloes may be summarized as follows:

Breeding and Reproductive Physiology

Rigor (1947) reported that carabaos may be bred in any month of the year, but greater sexual activity (69.2%) occurs during the months of August-January, which coincides with the rainy season and cooler months. Incidentally, calving incidence is also heaviest (63.5%) during this period.

Similarly, with the CLSU purebred herd of Murrah buffaloes, sexual activity has been observed through the year but is most pronounced from September-January, a period which accounted for 74.1% of the buffalo cows bred during the year. Likewise, 75.6% of calving occurred from August-November, which tends to coincide with the wet season and cooler months of the year in the Central Luzon region (Eusebio *et al.* 1965).

The major reproductive problems observed among carabaos and other water buffaloes are late maturity, low conception rate, long calving interval, high incidence of silent heat, and poor semen quality.

Results of studies on the reproductive phenomena of buffaloes in the Philippines are summarized in Table 2. It is apparent from the data that carabaos, Indian buffaloes and their crosses are late maturing animals with long gestation periods and calving intervals.

In the carabao, the oestrous cycle averages 20-22 days and the duration of oestrus 18-24 hours; ovulation time is 10-15 hours from the end of oestrus, or 33-35 hours from the onset of oestrus. Ovulation occurs more frequently at night than in the daytime. Vinh *et al.* (1976) indicated that, in caraheifers, most oestruses occurred at night and

Table 2. Some reproductive phenomena of buffaloes in the Philippines.

	Philippine Carabao	Indian Buffalo	Crossbred Carabao	Source
Age at first fertile mating, (yr)	2.42	2.21 3.50	2.32	Villegas 1979 Eusebio *et al.* 1965
Age at first calving, (yr)	3.64	4.77	3.06	Ocampo 1937 Eusebio *et al.* 1965
Interval between calvings (days)	415	520 435	502	Ocampo 1937 Eusebio *et al.* 1965
Interval between calving and first oestrus, (days)	35	50 49	44	Ocampo 1937 Eusebio *et al.* 1965
Gestation period, (days)	320	— 314	315	Villegas 1979 Eusebio *et al.* 1965
Oestrous cycle, (days)	20.9 ± 2.7 21-22 22			Vinh *et al.* 1976, Wongsrikeao 1979, Wagelie *et al.* 1980
Oestrus duration, (hr)	18.5 ± 6.9 21-22 24.1			Vinh *et al.* 1976, Wongsrikeao 1979, Wagelie *et al.* 1980
Ovulation time from end of oestrus, (hr)	15.3 ± 1.7 11-13 7.2-13.3			Vinh *et al.* 1976, Wongsrikeao 1979, Wagelie *et al.* 1980
Ovulation time from onset of oestrus, (hr)	34.9 ± 12.7 33-34			Vinh *et al.* 1976, Wongsrikeao 1979

terminated in the morning. Daytime oestruses also occurred. Ovulation was left-sided in 63% of 81 cases.

Wongsrikeao (1979) reported that a single injection of 30 mg of PGF_2alpha, or two injections of 30 mg each at an interval of 12 days, gave pregnancy rates of 50% or higher.

The quality, freezability, and fertility of Murrah buffalo semen are being studied at NABC. The semen is slightly yellowish in colour, volume per ejaculate averages 2.4 ml with a concentration of 820-1895 million spermatozoa/ml, and an initial motility of 7-80%. Live spermatozoa range from 85-97%. Semen pH is 6.0-7.2 and methylene blue reduction time is 3.0-7.0 minutes. An average recovery rate of 52% after freezing has been obtained from samples stored for seven months. Field trials carried out on 565 caracows and grades gave average conception rates of 47-56% (Wagelie *et al.* 1980). In all cases, pregnancy diagnoses were conducted 90 days after inseminations. The optimum time to inseminate female carabaos appeared to be between the 19th and 26th hours after the onset of oestrus. This has resulted in conception rates of 61 and 54% with refrigerated and frozen semen, respectively. The optimum spermatozoa concentration per ml is 120 million, giving a conception rate as high as 51%.

Signs of heat in the buffalo are barely noticeable and, therefore, difficult to detect. This phenomenon is one of the factors responsible for the low conception rate with AI in buffaloes.

Rajamahendran *et al.* (1983) reported that physical behaviour and histological studies suggest that no single parameter studied could be used as a sole criterion to detect oestrus in buffaloes. They indicated that elevated rectal temperature (in 75% cases) and increased vulva area (85% cases) were observed to occur during the periods of expected oestrus. Also, formation of ferning pattern (50%), presence of keratinized cells (75%), and uterine turgidity (50%) were seen to be the other pronounced features during expected oestrus. These parameters, however, pooled together and related to progesterone concentration, may facilitate detecting oestrus more satisfactorily in buffaloes.

Ranjan (1983) indicated that the conception rate from natural mating in buffaloes ranges from 50-70%, but that from frozen semen from imported bulls used for AI was 25-40%, which is considered low. There are many factors responsible for this low conception rate. Despite established techniques, fertility rates vary from 10-40%. At the FAO/UNDP-PHI 78/017 R & D Carabao Centre, a conception rate of 33.3%, with a single dose after heat synchronisation, though encouraging is still rather low. The use of heat-inducers to synchronize heat appears to be a promising strategy that can complement the AI program in buffaloes.

Under the FAO/UNDP-PHI project, frozen semen of Murrah, Nili-Ravi, and Thai buffaloes is being imported from India, Pakistan, and Thailand, respectively, for AI of the Philippine carabao. To date, 400 inseminations have been made in a population of 1209 breeding females from the institutional herd and farmer cooperators, with 127 crossbreds being produced. In the field, *inter-se* mating of F_1 will be resorted to in order to fix the exotic blood level at 50% until such time as research results show the optimum proportion of Murrah blood to achieve maximum production of milk, meat, and draught power from the crossbreds in the field.

Work Capacity of Buffalo

Buffaloes are well suited for work in paddy fields. They are slow, but heavy and strong, and are able to pull heavier loads than cattle especially in muddy and submerged fields. Local studies on the work capacities of carabaos and other buffaloes are very limited.

Villegas (1958) reported observations on the performance of the Philippine work carabao showing that the average area of sugar cane and corn field ploughed to a depth of 10.7-15.2 cm was 3044 m^2 for an average of 17 working hours; for lowland rice field ploughed to a depth of 16.7 cm the area was 4365 m^2 during 8 working hours.

The studies of Salas (1980) on 15 work Murrah-Carabao crossbreds, 3.5-4.0 years old with an average weight of 407 kg, revealed that in pulling a load of 150 kg on a sled for 20 minutes, the average registered draught force was 65.01 kg and the calculated drawbar horse power was 77.35 kg-m/sec (1.01 h.p.). In the ploughing operation on a 100% saturation Maligaya clay loam soil, the registered average draught force was 116.15 kg; the calculated power was 131.57 kg-m/sec at an average speed of 1.035 m/sec.

According to Cockrill (1974) heavy animals such as buffaloes work mainly with their weight and he indicated that buffaloes weighing 400-900 kg can create a power equivalent to 0.75 h.p. compared with a light horse of 400-700 kg liveweight that can develop a draught power of 60-80 kg at an average speed of work of 1 m/sec or equivalent to 1.00 h.p.

The carabao and their crossbreds certainly will remain a major source of draught power for farm tillage and transport in the Philippines and due to rising cost of oil, farm machinery, and spare parts, they will more than justify efforts to improve the work capacity of this animal through breeding in terms of body weight and size.

Production and Utilization of Carabeef

Carabao meat, which is technically known as 'carabeef', is always associated with beef. It is a very good source of animal protein and could be used, not only to substitute importation of beef and other meat preparations, but also to narrow the gap of protein malnutrition in the country, especially of the young sector of the population. In the Philippines, carabeef contributes about 49% to the domestic beef industry, indicating the significant role of the carabao in supplementing meat production from cattle, contributed by an annual extraction rate of 5% or more of its population.

The average liveweight of carabaos and Murrah buffaloes under normal feeding and management is shown in Table 3. The Indian buffalo is definitely heavier and bigger than the carabao from birth to maturity, and on average, males are about 10% heavier than the females in both breeds. It is important again to mention that nutrition and management will affect growth and size of carabaos and buffaloes.

A number of studies have been conducted on the characteristics of carabeef involving carcass yield, physical and chemical composition, and sensory characteristics of the meat. The data of Calub *et al.* (1971) on the carcasses of 11 male buffaloes 2.5 years old and 13 grade steers (Red Sindhi x Holstein-Friesian) 3 years old showed that buffalo meat had a significantly higher marbling score than cattle meat, although the latter had a significantly longer carcass and larger rib eye area than the former. However, no significant differences were obtained between cattle and buffaloes in chilled carcass weight, dressing percentage, chilling shrinkage, trimmed saleable cuts, lean trimmings, fat and ligament trimmings.

Table 3. Average liveweight of carabao and Murrah buffaloes*.

Age	Philippine carabao Castillo (1975) (kg)	Murrah buffalo Eusebio *et al.* (1976) (kg)
Birth	28	32
6 months	88	135
1 year	170	193
2 years	260	306
3 years	335	382
4 years	398	465
5 years	448	515
6 years or older	510	550

*Average combined weight of male and female animals.

Dagdagan and Marciano (1973) reported that sex, finish, and age did not affect the yield and other carcass characteristics of the buffaloes studied. However, the percentage of the forequarters of carabulls was slightly higher than that of either carasteers or caracows, but differences were not significant.

The study of Arganosa *et al.*(1973) showed that carabeef had significantly higher crude protein (20.20%) and cholesterol (64 mg/100 gm) than the 19.2% crude protein and 54.8 mg/100 gm cholesterol found in beef. Also, the total pigment and myoglobin content of carabeef was significantly higher than in beef, which explains why carabeef is usually darker in colour than beef. The chemical composition of beef and carabeef is shown in Table 4.

Table 4. Chemical characteristics of beef and carabeef.

Characteristics	Cattle	Buffaloes
Crude protein (%)	19.20	20.20*
Ether extract (%)	1.13	1.03
Ash (%)	1.10	1.11
Nitrogen-free extract (%)	2.28	3.24
Moisture (%)	76.29*	74.42
Total pigment (mg/gm)	2.30	4.10*
Myoglobin (mg/gm)	1.50	2.50
Cholesterol (mg/100 gm)	54.80	64.00*

*Significant at $P < 0.05$.

Results of sensory evaluation tests on beef and carabeef showed no significant differences in any of the criteria scored by trained and consumer panels. This suggests that beef and carabeef from animals of about the same age and reared on the same plane of nutrition have indistinguishable eating qualities (Calub *et al.* 1971).

Several studies have been conducted on the use of carabeef in the preparation of many meat products:

fresh sausages (Esguerra 1972); Chinese style and salami sausages (Almira 1972); bologna sausages and meat loaf, frankfurters and corned beef (Florencio and Sonido 1973); 'Kroepect', a gelatin chip product (Aducayen *et al.* 1973); carabeef liver for liver sausage (Marero 1978); concentrated canned meat stew (Ramirez 1978); and the use of carabeef for some popular Philippine recipes (Reyataza 1978); All the results showed no appreciable differences in terms of colour, tenderness, juiciness, and general acceptability between carabeef and beef.

It could be concluded from these data that, in relation to nutritional and sensory values, carabeef is as good and acceptable as beef when the animals are similarly fed and managed and slaughtered at comparable ages.

Milk Production

The Philippine carabao as a beast of burden is generally a low milk producer. This is compounded by the very poor feeding and management practices provided mostly by subsistence farmers whose resources are generally limited. It may be pointed out that feed is a very important factor affecting milk production, and good feeding and management are imperative to obtain maximum milk output.

The colour of buffalo milk is bluish white compared with the yellowish colour of cow's milk. The absence of yellow colour in buffalo milk is due to the animal's high efficiency in metabolizing the carotene (xanthophylls in green feed) in the feed to vitamin A.

Castillo (1975) cited data on the chemical composition of carabao and buffalo milk. The fat and total solids contents of milk from the Philippine carabao are appreciably higher than those from the Indian and Egyptian buffaloes.

Carabao milk is either consumed as market milk or generally processed into white, soft cheese that is an old home industry in the Philippines. Studies at UPLB-DTRI have shown the potential utilization of carabao milk in the manufacture of cottage cheese spread, cheddar type cheese, ice cream, and confectioneries.

Eusebio (1975) reported results of a study on the economics of milk production with the CLSU Murrah buffalo breed herd of 39 cows and 2 bulls. They showed a yearly gross income of P63 104.80 with a total expenditure of P42 161.21 of which 61% went to variable costs and 39% to fixed costs. The net return realized was P20 943.59. One kg of milk cost P1.38 to produce and sold at P1.80, giving a net return of P0.42 or a rate of return of 30%. The costs of production of buffaloes 1, 1.5, 2, 2.5 and 3 years old were 850, 1100, 1350, 1600, and 1950 pesos, respectively.

Future Outlook of the Philippines Carabeef Industry

The present worldwide problems of energy, inadequate food supply and rapidly expanding population pose great challenge to any effort at national development, particularly in developing countries like the Philippines. The domestic demand, therefore, for animal products and the need for more draught animals for farm work and transport are expected to increase substantially in the next decade.

Fortunately, the PCARRD program on buffalo research and development, both at the national and regional levels, coupled with the strengthening of the institutional framework for these activities, are significant strides towards meeting these needs. Moreover, the project on strengthening the Philippine Carabao Research and Development Centre with assistance from FAO/UNDP, USAID, and the Philippine government are solid manifestations of promoting the accelerated attainment of a developed and improved domestic carabeef industry. In this context and perhaps with more innovative development strategies, the prospect of the Philippine carabeef industry certainly looks very bright and promising in the years ahead.

Summary and Recommendations

The situational analysis of the Philippine carabeef industry has been presented indicating the economic importance of the carabao in terms of draught power and production of meat and milk to augment the food and nutritional needs of the expanding population in the country. With the carabao being a familiar but untapped farm resource, it would certainly be a logical development strategy to make this animal more productive and efficient. However, technical constraints limiting efficient carabao production and utilization are well recognized. Thus, among the major problem areas needing attention are: (1) low productivity attributed to genetically poor breeding stock, low standard of feeding and management practices, and reproductive problems; (2) an inefficient marketing system and poor credit facilities; and (3) ineffective extension services.

In the light of the present development, suggested areas for collaborative research should be focused on reproductive physiology, nutrition, and pasture development and improvement.

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Recent Research and Development Programs to Improve Buffalo Productivity in Thailand

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AGRICULTURE in Thailand is largely dependent on animal power for farm operations. Mechanized farming is very limited in extent and distribution. The small size of the farm holdings and their large number are characteristics shared by many countries in Southeast Asia. The swamp buffalo is the main source of animal power on the small farms and has traditionally been found to be ideally suited for the agroclimatic conditions and feed resources of Thailand. It is hard to replace the buffalo on the small farms by other economic sources of power.

Buffalo production in the country has, however, suffered long neglect. The projection of population figures for the year 2000 shows that, besides the animals that would be needed for farm operations, 1.2 million head of buffaloes and cattle will be required annually to meet the needs of domestic meat consumption. In addition, more animals would be wanted to feed the expanding livestock export trade.

There is, therefore, great need and scope for developing buffalo production in Thailand. The National Buffalo Research and Development Centre Project was founded in 1976 to improve buffalo productivity, taking advantage of the collaboration of scientists from several institutions. Within the framework of this project, work has been carried out on reproductive physiology, AI, breeding and production, health science, feeding, and nutrition. The recent research from 1977-1982 has resulted from the guidelines for multidisciplinary research needed for buffalo production at the small farm level. Accuracy of inventory records is needed before any development program is commenced. The aim is to maximize productivity of buffaloes on small farms by the application of technology based on scientific research. Research by scientists in Thailand and the collaboration of scientists outside the country will be important for this direction of development. Buffaloes in Thailand should be exploited for meat as well as for their main function as draught animals. However, this will require suitable improvements to the existing regulations governing slaughter and production of meat, and the pricing and marketing systems, together with the introduction of a grading system for meat that meets international standards.

Exploitation of the buffalo in Thailand for increased milk production has a place in the context of a developing rural economy, and needs consideration as a long-range objective.

The Profile of Agriculture

In the past, Thailand's economic development and trade have been based chiefly on agricultural production. It will continue to be so in the foreseeable future.

The average farm holding in Thailand is 15-25 rai (1 rai = 0.16 ha), a farm size that is inadequate for full-scale livestock agriculture and is too small for economic operation with mechanized agriculture and modern technology. The developing trend for fragmentation of small holdings has added to the problem of increasing agricultural productivity. Even so, agriculture is inevitably centred on the millions of small holdings, and the development of agricultural production must be within the existing system of farms. With the ever increasing cost of fuel and with Thailand's high proportion of unmechanized agriculture, small-scale farming will continue to depend on animal power. In increasing agricultural productivity, integrated livestock production will therefore play a large role. The need for work animals is expected to increase in coming years. The official estimate (Division of Agricultural Economics, Ministry of Agriculture and Cooperatives) of the annual national requirements of animals for work, in the immediate future, is 2 million buffaloes and cattle.

A large section of small farmers, who are also the poorest, practice rain-fed agriculture out of necessity, depending on the rain and the seasons for their cultivation. Their land holdings, though relatively large, are not productive because of the lack of resources. Associated with this is the under-utiliz-

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ation of land, because the shortage of draught animals on the farm does not enable the farmer to prepare all the available land in time for the cultivation season.

To raise the productivity of small farms, make fuller utilization of land and develop rural prosperity, the farmer must increase the number of his working buffaloes and their working capacity. This will enable him not only to complete the cultivation in time, but also utilize family labour more and increase his income in two ways: directly from crops and indirectly from buffalo production. The introduction of low-cost technology, like the provision of improved agricultural implements particularly suited for working small farms with buffaloes, would contribute significantly to better production.

Buffalo and Draught Capacity

Using the traditional plough a buffalo takes 13 h per rai to prepare the land (furrowing and harrowing) for the cultivation of rice or for upland crops, with furrows 10 cm wide and 10-12 cm deep (Kamonpatana and Walker 1969). In the north-eastern areas, working 7 h per day, the estimate is 4 days per rai for preparation of land or 22 rai in 3 months (Bhannasiri 1974).

Both the male and female buffalo are used for work. They are trained and put to work at 3-4 years, but not earlier, and have a long and useful working life span of 10-12 years (Buranamanas 1963). At an average age of 13.9 years they become physically unfit for farm operations and are normally sold for meat. The number of days in a year that the animals are worked ranges from 56-146, the lower the figure applying to central Thailand where some mechanized farming is practised (De Boer 1972).

Buffaloes are usually fed non-marketable rice straw. However, other farm by-products like corn stovers, kenaf and cassava leaf, sugar cane tops, crop residues, and vine stalks, depending on the pattern of crop production in different parts, could also find extensive use in livestock feeding. The free availability of these would make it possible to use buffaloes for farm work all over the country.

The State and Movement of Buffalo Production

The buffaloes of Thailand and other parts of South-east Asia belong to the swamp type, *Bubalus bubalis*. There are at present about 6.5 million farm families and 45.9 million rai of land for crop production. The annual increase in population of buffaloes, which was only 0.05% during 1963-1969, has been even lower since 1970 (Kamonpatana 1981). Major factors that account for the declining population growth rate are the low breeding efficiency of the female, the poor breeding qualities of the male, and high calf mortality. At the same time, more animals than before are being used for meat due to an increase in meat consumption. Domestic beef consumption has increased rapidly since 1975. Also more buffaloes are exported to neighbouring countries for meat purposes. The problems arising from this situation are aggravated by the annual growth rate in human population—2.7% projected estimate. This situation has been realized by the national planning and decision makers, and is important to livestock development technologists.

To avoid a crisis, strategies for scientific exploitation of the full potential of the buffalo are needed. Better knowledge about the buffalo will increase its usefulness as a source of farm power, low-cost animal protein, and milk for child nutrition. This report will illustrate the progress of research during 1977-1982 that has been giving a guideline to the development program for improving productivity.

Potential of Buffalo Research and Development

The buffalo research and development program was initiated at national level in 1971. In 1974 the research team at Chulalongkorn University was funded by the University under the Rachadapisek-sompot Research Fund to inititate research on reproductive physiology and AI. In August 1975, a Memorandum of Agreement on buffalo research cooperation was signed. The Department of Livestock Development is the centre of coordination. Kasetsart University joined at the beginning and was followed by Chulalongkorn University, Chiangmai University, Khon Kaen University, Institute of Agricultural Technology (Chiang Mai), Surin Agricultural College, and Prince of Songkla University.

The project was formulated to control the direction of the development program and gradually made progress on buffalo research in various disciplinary studies in order to fill gaps in knowledge. It is now a multi-agency project. From 1977-1982, the project produced annual reports that collected all the research works that had not been published elsewhere. A total of 213 scientists, 73 in reproductive physiology and AI, 33 in breeding and production, 47 in health science, and 60 in feeding and nutrition were able to publish 120 papers in the annual reports during 1977-1982 (Table 1).

Table 1. Publications on buffalo research and development in Thailand during 1977-1982, presented in Annual Reports, The National Buffalo Research and Development Centre Project.

Fields	No. of Papers							No. scientists
	1977	1978	1979	1980	1981	1982	Total	
Reprod. & AI	8	8	7	11	5	8	47	73
Breeding & production	0	7	5	3	5	2	22	33
Health science	0	9	4	5	5	12	35	47
Feed & nutrition	5	2	4	5	6	4	26	60

Quite a number of papers were published in international journals or proceedings, particularly on reproductive physiology, AI, breeding, and production.

The sources of support for buffalo research are mainly from the Government, university, international aid, and bilateral aid programs. The Government has supported selective activities that progress from research to promotion of development on a large scale. But there are still quite a number of areas in which results are not substantial enough to put at the level of implementation. Details will be described in the above-mentioned various fields.

Reproductive Physiology and Artifical Insemination

Studies of buffalo reproduction and AI have been undertaken in areas of general reproductive data, physiology and environment, oestrus detection, endocrine control in the female, hormone assays and applications, synchronization of oestrus, endocrine factors in the male, semen studies, and AI and related techniques.

For general reproductive data, collection is still underway. Reproductive performance of breeding herds in the governmental stations has been reported by Usanakornkul *et al.* 1978 and Pongpairoj *et al.* 1978. Work on identification of reproductive patterns has not been completed, but some work has been done on parturition, uterine involution, and postpartum morbidity (Wecharatpimpol and Mongkonpunya 1977; Harbers 1980). Biometry of the reproductive tract has been reported by Lohachit *et al.* 1979. A cytological study to identify the chromosome constitution in the swamp breed and the cross with the river breed was undertaken to characterize the strains (Songsri 1979; Chuanchai 1981).

Environmental factors and disease control may play important roles in increasing productivity in buffalo, particularly for meat and milk production. Research in this area is just beginning and further investigation is necessary. The effect of heat stress on physiological functions in the body has been studied (Chaiyabutr *et al.* 1983).

Oestrus detection becomes a problem for the extension of AI in the swamp buffalo. Oestrus symptoms in this species appear very weak. An intensive study of behaviour has been carried out in the Surin breeding herds. Oestrus detection in the swamp buffalo for the use of AI at the small farm level is still a problem requiring greater skill by farmers. The work has been intensively carried on by comparing observations made by the farmers and results of progesterone tests. The most useful symptoms identified will be fed back to the farmers (Kamonpatana *et al.* 1982a). A great deal of effort has been devoted to the areas of endocrine control in the female, hormone assays and applications, and synchronization of oestrus. It is realized that the more knowledge we obtain, the more progress we make towards improving reproductive efficiency.

The low reproductive capacity of the buffalo has long been recognized. To improve reproductive efficiency in the swamp buffalo, a better understanding of basic endocrine patterns is required. Hormonal determinations in conjunction with clinical examination have assisted in the determination of normal reproductive patterns and their endocrinological basis. This in turn provided the necessary foundation for investigations on the causes of reproductive inefficiency and allowed the examination of possible methods for improving reproduction.

For female buffaloes, the progesterone and oestrone sulphate profiles associated with the oestrous cycle, pregnancy, parturition and the postpartum period have been established for the swamp breed (Kamonpatana *et al.* 1976, 1979a, 1981a, and 1983). Attempts have been made to investigate the role of pituitary gonadotrophins (LH, FSH and prolactin) during the oestrous cycle, pregnancy, parturition, and postpartum (Kamonpatana *et al.* 1978, 1981a).

Intensive studies during the postpartum period have been carried out but no further work on hormonal regulation in relation to the onset of postpartum cyclicity has been tried. Swamp buffaloes under the management at the Surin station commence oestrus cycles 23-25 days after parturition (mean ± SD = 92 ±42 days, n = 55). The period seems to be influenced by the season of calving. It was shown that cows calving during April-July commence oestrus activity later than cows calving during August-October or during January-February (Table 2). Oestrus was detected by vasectomized bulls run with the females every 6 hours. Oestrus symptoms were recorded as oestrus, suboestrus.

Table 2. The commencement of first oestrus postpartum (pp) in 55 buffalo cows in the hot season (April-July), rainy season (August-October) or dry season (January to February) in Surin breeding herds.

Seasons of calving	No. animal	Days pp to first oestrus	Mean ±SD	% 1st oestrus commencing before 90 days pp
Group I	1	86	—	5.56%
April-July	8	113-129	122 ± 5	
(hot season)	4	132-144	138 ± 5	
	5	151-215	177 ± 28	
Sub-total	18			
Group II	2	42	—	93.75%
August-October	7	56-70	65 ± 5	
(rainy season)	6	71-90	77 ± 7	
	1	106	—	
Sub-total	16			
Group III	2	23-26	25 ± 2	66.67%
January-Feb.	6	37-50	44 ± 7	
(dry season)	1	69	—	
	5	73-90	80 ± 6	
	5	96-110	103 ± 5	
	1	113	—	
	1	134	—	
Sub-total	21			
Total	55	23-215	92 ± 41	

From these animals we determined that the cows with weak signs of oestrus showed low oestrone sulphate, whether the progesterone was high or low (Kamonpatana and group, unpublished).

Endocrine methods for oestrous synchronization have been developed and applied (Kamonpatana *et al.* 1979a, 1982c; Virakul *et al.* 1981; Chantaraprateep *et al.* 1982) and determinations of oestrone sulphate and progesterone have been used for assessing pregnancy status (Kamonpatana *et al.* 1979b, 1981b, 1982b).

For male buffaloes, diurnal variations in testosterone and LH levels have been established in buffalo calves and bulls (Kamonpatana and group, unpublished; Kamonpatana *et al.* 1979c; Chantaraprateep *et al.* 1981). Further attempts should be made to clarify the possible relationships between testosterone secretion and libido, semen characteristics, and seasonal influence.

In the near future, these studies should help in decreasing the calving interval, improving heat detection, finding the causes of subfertility, and in selecting sires. Such measures should increase buffalo productivity and population growth.

Artifical insemination of swamp buffalo in Thailand has been practised at the small-farm level since 1978 by the Division of AI, Department of Livestock Development. The number of animals served per annum has gradually increased from 1000 in 1980 to 2000 in 1983 (Table 3). Conception rate was around 50% from the first insemination and around 65% from the final insemination. Numbers of services per conception were 2.25.

Table 3. The development of buffalo AI in Thailand during 1980-1983, presented in terms of numbers of animals inseminated, calves born, services per conception, and conception rates from first and final inseminations.

	1980	1981	1982	1983
No. of animals inseminated	1 184	1 349	2 425	1 992
No. of calves born	199	417	926	914
% calving	16.81	30.91	38.19	45.88
No. of services per conception	2.11	2.13	2.40	NA (not available)
% CR first AI	54.90	55.30	49.94	NA
% CR final AI	64.86	66.79	62.43	NA

CR = Conception rate.

From these data about 50% of the buffaloes were inseminated 4.5 times to raise the conception by a further 15%. This means that half of the animals pose the difficulty of heat detection. Heat detection is still a major problem for the wide application of AI. Based on the progesterone data (Table 4), 11% of buffaloes were inseminated at the wrong time and only 20.75% conception could be obtained from the first AI. This agreed well with the results obtained from China, Malaysia, and Sri Lanka.

Table 4. Results of first inseminations of swamp buffaloes under the routine AI service, discriminated by progesterone (P) tests. Heat was observed by the farmers.

Discrimination by P test	No. animals	P (ng/ml)		%
		at day AI	after day 24	
Pregnant	22	0.10	1.40	20.75
Non-pregnant	63	0.08	0.12	
Doubtful	9	0.07	0.07	
Not on heat at AI	12	1.46	0.87	11.32
Total	106			

In comparison, the conception rate by oestrus synchronization with two fixed times of insemination, 42.71% (Table 5) suggests that oestrus synchronization may be employed when oestrus detection is still not efficient.

Table 5. Results of two fixed-time inseminations of swamp buffalo under oestrus synchronization, based on the progesterone (P) test.

Discrimination by P test	No. animals	P (ng/ml)		%
		at day AI	day 24 after	
Pregnant	41	0.05	2.46	42.71
Non-pregnant	63	0.04	0.12	
Doubtful	7	0.13	0.65	
Not on heat at AI	2	0.83	1.23	2.08
Total	113			

Due to the low conception rate with AI in swamp buffalo, more effort should be put into research on the male, particularly on semen characters and components concerned with deep-freezing of semen. For females, one should focus on oestrus detection, and identification of the optimum time postpartum for service to give maximum conception rate. Postpartum anoestrus is one of the critical causes of reproductive failure in swamp buffalo. The results produced in this area are not sufficient to support any kind of improvement. Further study is needed in terms of effects of suckling on endocrine responses, and calf nutrient requirements, in order to identify the critical components and to determine the management systems that will help to give full reproductive potential on small farms.

Calf mortality is also one of the major problems affecting net reproductive efficiency. Surveys indicating 25-30% calf mortality have stimulated efforts to determine the causes. Controls of parasitic infection and suckling management hold promise of preventing this loss.

Breeding and Production

Studies in the field of breeding and production in the last six years have been in the areas of buffalo production at the village level, breeding and production as a function of managerial practices, and seasonal influences and manure production. Buffalo production at the village level was low compared with experimental studies that permit the evaluation of output when some technology is injected. Some basic data on reproductive performance, liveweight change due to seasonal influence, and price and description of animals sold were reported (Mongkonpunya 1978, 1981; Niumsup and Songprasert 1978; Attamangkune *et al.* 1980). Programs of genetic selection and performance testing are carried on at the Surin buffalo breeding centre and Lumpayalkong breeding station. The studies of breeding, production, and managerial practices under these programs suggest that the swamp buffalo has a high potential for improvement for meat production (Chantalakhana and Na Phuket 1979; Chantalakhana 1983).

Health Science

Most of the research on health of the swamp buffalo in the past six years has been focused on parasitic infection, especially in buffalo calves. *Neoascaris vitulorum* is the most important parasite in buffalo calves. The incidence of this parasitic infection was found as high as 100% in swamp buffalo calves in Thailand (Sukhapesna 1983). The diseases that most commonly affected the buffaloes were haemorrhagic septicaemia and foot-and-mouth disease in which all three types (0, A and Asia-1) were enzootic (Table 6).

Table 6. Incidences of foot-and-mouth disease (FMD), haemorrhagic septicaemia, and anthrax in buffaloes during 1979-1982 (Department of Livestock Development).

Year	1979		1980		1981		1982	
Total No. buffalo (,000)	6 012		5 983		5 427		5 388	
Diseases	infected	died	infected	died	infected	died	infected	died
FMD	5 204		42 786	25	8 719	22	3 925	
Haemorrhagic	—	191	—	221	—	370	13	258
Anthrax	—	5	—	14	—	10	—	5

In regard to other diseases, reproductive disorders in particular have resulted in the population remaining static in recent times. Low conception rate, delayed maturity, infertility in cows, and sterility in bulls have been cited as factors responsible. Reproductive disturbances due to brucellosis, trichomoniasis and campylobacteriosis, malnutrition and mineral deficiency may affect productivity (Tesprateep, pers. comm.).

Calf mortality was high at 25-30% mainly due to parasitic infection and possibly increased by heat stress and poor management. Further application of a scheme to combine vaccination with deworming would markedly increase calf survival. This prevention appears necessary for increased productivity.

Feeding and Nutrition

Numbers of papers were produced in the last six years on pasture and other forages (Manidul and Sophon 1979; Veerasil *et al.* 1979), agricultural by-products and wastes (Intaramongkol *et al.* 1977; Hutanuwatr 1980; Wanapat *et al.* 1982) and evaluation of feeding improvement (Intaramongkol *et al.* 1979; Sanitwong *et al.* 1982). Even so, no new strategy has been formulated for feeding buffaloes in a production system.

It is nevertheless appropriate to review, discuss, and bring together the existing available information. Then it is possible to identify the gaps in our knowledge of feeding and nutrient requirements in swamp buffalo. In Thailand, beside non-marketable rice straw, other farm by-products like corn stover, kenaf and cassava leaf, sugar cane tops, and crop residues, can find extensive use in buffalo feeding. In this context, it is promising that further studies on feeding systems based on highly fibrous diets may lead to systems of raising buffaloes for meat in confinement on medium-size farms. The scope for utilizing agricultural by-products must rely on the established knowledge of ruminant metabolism and digestion to determine suitable rations. The most important approach is to maximize the output of knowledge by the way of research involving collaboration of local scientists with scientists from countries advanced in this discipline.

Development Programs for Buffalo Productivity

The exploitation of the full potential of the buffalo for work, meat, and milk must have high priority in the national agricultural development strategy of Thailand. The aim would be to enable small farmers to contribute their maximum to agricultural growth and, in return, derive more direct benefits from increased productivity. Besides efforts for raising the quality and number of buffaloes, the strategy should be directed at the integrated development of the assets of the farmer, viz. land, labour and livestock, and improved marketing and production systems. This will require an enormous input to the whole complex of agriculture.

For buffalo production, the Government has been actively supporting the following four main programs to increase buffalo productivity.

1. Establishment of several state farms to promote breeding and genetic selection programs, at the Surin Buffalo breeding centre, Lumpayakalang breeding station, and Surathani breeding station.

2. Establishment of a dairy herd with 110 head of Murrah buffaloes imported from India, at Nong-Kwang breeding station to promote various studies of crossbreeding programs.

3. Strengthening AI activity by establishing a bull station at Khon Kaen AI station to produce semen which is deep frozen at Patumthani AI centre for distribution to AI stations around the country.

4. Launching of a project on the use of nuclear techniques to improve reproductive efficiency in dairy cattle and buffalo, at Chulalongkorn Univer-

sity, Faculty of Veterinary Science. The project will concentrate on the use of the progesterone test to monitor reproductive efficiency, reproductive performance, and endocrine regulation with the aim of increasing productivity in terms of population growth.

The ongoing research activities have made possible methods for achieving these goals of development. However, further knowledge produced under the umbrella of these programs will help future achievement.

Areas of Improvement

To identify the areas of improvement of buffalo productivity, one should consider what could be immediate achievements and what may be long-term achievements. The majority of buffaloes in Thailand are owned by small farmers and kept mainly for working. Under the present agricultural system, it is hard to imagine that any genetic progress, even with technology based on science, is going to increase the productivity per head at the village level. Reproductive efficiency and calf survival could be areas to improve for immediate achievement of increase in population. However the future development of raising buffaloes for meat consumption must rely on young stock produced in excess by the small holders and collected into fattening operations. The creation of middle-size farms to utilize fibrous plant material produced throughout the whole country will provide an opportunity for the input of science and technology. Increased productivity per head may be foreseen in such a system.

To improve reproductive efficiency, the areas needing attention are: to improve calf survival by nutrition and health, to reduce age at first calving, and to decrease calving interval. These measures need to be achieved both in the breeding herds and at village level.

In Thailand, research and development initiated in the last decade could provide basic biological and sociological data. It is important to evaluate economically the results of any programs based on science and technology. Then the long-term objective of increasing productivity will become possible.

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Beef Cattle and Buffalo Breeding in Thailand

Charan Chantalakhana*

IN 1982, there were 6.4 million buffaloes and 4.6 million cattle in Thailand (Tables 1 and 2, and Figures 1 and 2). These animals are generally raised for work in crop production, especially where rice is the main commodity in the integrated farming systems. Most rice production depends on the use of buffalo and cattle for land preparation, transportation, etc. The use of animals for draught is quite suitable economically and socially, especially where farmers live in remote areas and own only small parcels of land, while family labour is available whenever needed. Buffalo or cattle production is not regarded as a distinct enterprise; rather, it is an integral part of a crop production system. In addition to providing the main source of draught power and manure to crop farming, cattle and buffalo also represent long-term savings, security in case of crop failure, etc., as well as a meat supply at the end of their life to town and city consumers. Commercial beef production in Thailand remains to be developed.

Table 1. Number of buffalo and cattle at April 1 during 1968-1982.

Year	Buffalo	Cattle
1968	5 549 933	4 290 256
1969	5 642 057	4 451 590
1970	5 734 500	4 666 969
1971	5 574 176	4 460 230
1972	5 361 338	4 484 962
1973	5 545 549	4 092 775
1974	5 641 834	4 149 791
1975	5 596 876	4 141 725
1976	5 895 418	4 322 375
1977	5 827 462	4 341 152
1978	5 958 734	4 436 607
1979	6 027 895	4 275 825
1980	5 650 794	3 938 221
1981	6 124 019	4 468 796
1982	6 417 433	4 578 699

Source: Agricultural Statistics of Thailand, Crop Year 1982-83, Ministry of Agriculture and Cooperatives.

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Table 2. Number of buffalo and cattle by region in 1982.

Regions	Buffalo		Cattle	
	Number (million)	%	Number (million)	%
Whole Kingdom	6.417	100	4.578	100
North	1.355	21.1	1.063	23.2
Northeast	4.264	66.4	1.746	38.1
Central	0.555	8.6	0.914	20.0
South	0.243	3.8	0.855	18.7

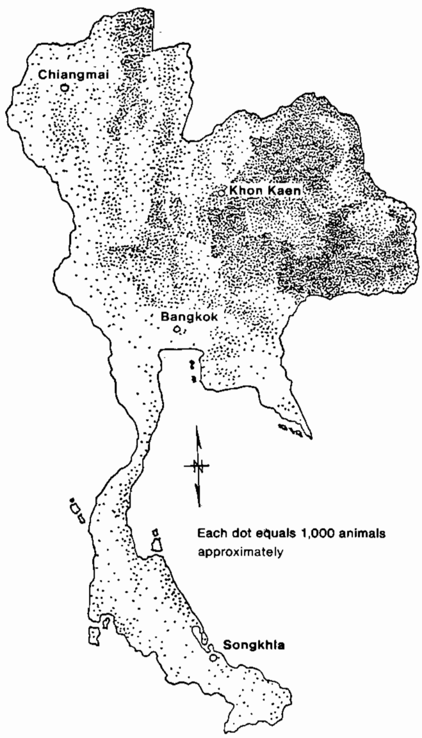

Fig. 1. Distribution of water buffaloes in Thailand (based on 1982 survey). Source: Office of Agricultural Economics, Ministry of Agriculture and Cooperatives.

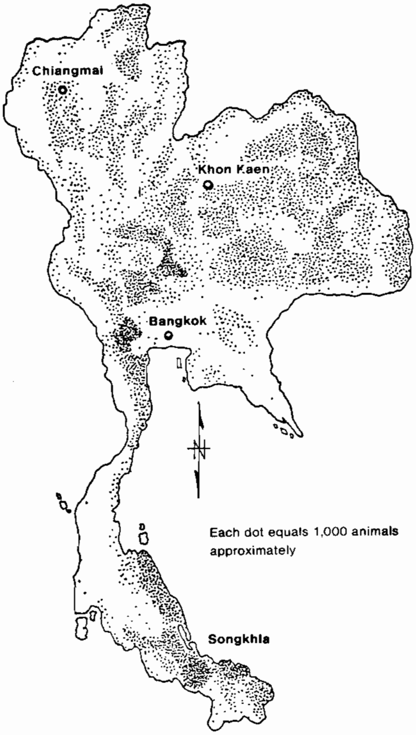

Fig. 2. Distribution of cattle in Thailand (based on 1982 survey). Source: Office of Agricultural Economics, Ministry of Agriculture and Cooperatives.

In most parts of Thailand, village farmers, who generally raise 2-5 cattle and/or buffaloes, usually set aside small plots of 0.2-1 ha for buffalo and cattle grazing to supplement other sources of grazing areas available in the village such as paddy fields, scrub forests on upland areas, highway shoulders, rice bunds, communal grazing lands, etc. In general, buffalo and cattle depend mainly on rice straw and stubble, while other crop residues such as corn stalks, cassava and kenaf leaves, etc. also provide substantial sources of roughage, especially during the dry season. Neither concentrates nor mineral supplements are given to bovines. Animals are generally kept under the house during the night where they are more safe from thieves. There are virtually no cash inputs used and most tending is done by family labour, i.e. women, children, or old people.

Practically all village-work buffaloes are the indigenous swamp type. Generally, they can be found in two colours, black or grey, and white, with about 3-15% of them being white. There is no scientific evidence so far to discriminate against the white buffalo as far as production and work abilities are concerned. There do exist, however, some traditional beliefs against white buffalo; for instance, some Thai villagers believe that white buffalo meat produces an allergic reaction in pregnant women, some believe that white animals belong to some mythical spirit, some contend that white buffaloes are not as resistant to sunlight as grey ones, etc. In contradiction, some villagers take white buffalo as good luck.

Buffalo breeding generally takes place through random natural mating with no colour discrimination. Within-breed breeding is commonly practised in the buffalo, with limited interest in crossbreeding the swamp type with Murrah buffalo (river or milk type).

Most cattle in Thailand are still the indigenous breed even though Brahman crossbreds can be found in many areas due to the introduction of Brahman bulls into villages by the Department of Livestock Development during the last 2-3 decades. The Brahman crossbreds adapt well under village conditions and are quite well accepted by the villagers. Some villagers raise high grade or even purebred Brahmans. Brahman and crossbred cattle generally command a much higher price per kg than that paid for buffalo or indigenous cattle. Production of crossbred calves is either through natural mating via the government bull loan program, by using privately owned bulls, or through the artificial insemination service. AI service, however, is generally limited to farmers who live near the AI stations. The demand for Brahman bulls by farmers continues to be high.

About 60% of the total cattle herd are for working, i.e. draught. Cattle bullocks are generally preferred for cartage because they move at a faster speed than buffalo. Villagers generally select bigger animals, both cattle and buffalo, to be castrated for work, since the castrated animals will become tamer and easier to handle.

Health care for buffalo and cattle is very minimal. Some may be vaccinated against certain infectious diseases, but most are not. In general, farmers do not buy any medicine to treat sick animals, preferring to use traditional curing methods practised since ancestral times.

Farmers rarely sell their buffalo or cattle, except on exceptional occasions. When they do, the sale generally occurs at the farmer's household. The buyer and the farmer will bargain on the price, which is determined by eye and experience.

Beef Cattle Breeding

The Thai Indigenous Cattle

Table 3 shows various traits of the Thai indigenous cattle. Their size and growth rates do not appear to be much different from those of the indigenous cattle in other South-east Asian countries, such as the Kedah-Kalantan in Malaysia, the Batanga cattle in the Philippines, or the Bali cattle in Indonesia. The mature weight of the female at a low level of feeding and management averaged only 226 kg, as reported by Chantalakhana (1983a), while the male could grow up to 375 kg. They are generally slow to mature, average age at first calving is about 4-5 years, with 40-50% calf crop, and a calving interval of 1.5 years (Chantalakhana 1983b).

Table 3. Various traits in the Thai indigenous cattle (Chantalakhana 1983a).

Traits	Unit	Estimates
Birth		
Weight	kg	14.8 ± 1.3 (M 14.9, F 14.6)
Body length	cm	28.0 ± 9.9
Heart girth	cm	60.0 ± 4.2
Height	cm	62.0 ± 3.3
8 months		
Weight	kg	122.2 ± 19.4
Body length	cm	56.2 ± 7.1
Heart girth	cm	117.0 ± 11.3
Height	cm	91.1 ± 2.4
Mature cows		
Weight	kg	226.7 ± 24.9 (306-183)
Body length	cm	88.2 ± 3.7 (92-77)
Heart girth	cm	145.5 ± 10.7 (157-135)
Height	cm	109.2 ± 5.0 (122-95)
Ave. daily gain	gm	
Pre-weaning		
M-castrated		430
-not cast.		460
Female		400
Post-weaning		
M-castrated		217
-not cast.		230
Female		165
Carcass		
Dressing percent	%	51.2
Length	cm	91.5
Loin eye area	cm^2	45.6
Cold shrinkage	%	2.6
Physiological Characters		
Haemoglobin	mb/ce	10-11
Haematocrit	%	40-43
Body temp.	°C	38.9-39.2
Respiration	per min.	24-30

Average calf birth and 8 month weights were found to be 14.8 and 122.2 kg respectively, with pre-and post-weaning daily gains of 400-600 and 165-230 gm respectively.

Imported Breeds

The Department of Livestock Development (DLD) started a beef improvement program in 1954 by introducing the first group of Brahman cattle from the USA for evaluation and crossbreeding. The Brahmans and crossbreds have become very popular among farmers in Thailand, supported by various research results concerning the crossbred performance. More Brahman cattle have been purchased from the USA and Australia for multiplication (Table 4). Other breeds such as Santa Gertrudis, Charolais, and Hereford have also been imported for breeding. The results from purebred breeding and crossbreeding have not been satisfactory so far, hence the interest in these breeds has been rather limited. Their half-breds with the indigenous cattle appeared to grow well under local conditions, but grading up to the taurus breeds produced inferior crossbreds, as far as growth, heat tolerance, and disease resistance are concerned.

Crossbreeding

Crossbreeding of the Thai indigenous cattle with other imported breeds for beef production has been conducted since the first introduction of Brahman cattle. In 1963, Yodseranee *et al.* reported some results from crossbreeding work conducted at a government livestock breeding station in North-east Thailand (Table 5).

The Brahman and Zebu gained on average 0.79 and 0.72 kg per day respectively, as compared with 0.57, 0.51, and 0.51 kg for the Brahman cross, Zebu cross, and indigenous cattle. At 21 months of age, Brahman, Brahman crossbred, and Zebu weighed 288.8, 249.3, and 232.2 kg respectively, while the Zebu cross and indigenous cattle averaged 215.7 and 203.6 kg. The results from this study indicated that crossbreeding of Brahman with indigenous cattle improved body weights and rates of gain in the crossbred. In this experiment, concentrate supplement was also given to the experimental animals, which were fed primarily on pasture grazing.

Chantalakhana *et al.* (1971) reported results from crossbreeding of indigenous and other local cattle with Red Sindhi, Hereford, and Charolais (Table 6).

Table 4. Introduction of exotic beef breeds into Thailand (Chantalakhana 1983a).

Breeds/Year	Source	Number			Remarks[a]
		Male	Female	Total	
Brahman					
1954	USA	24	47	71	RTG
1957	USA	101	30	131	US Aid
1966	USA	20	30	50	RTG
1967	USA	50	0	50	DLA, KU
1970	USA	63	38	101	RTG
	USA	5	28	33	Chokchai Ranch
1971	USA	52	61	113	RTG
1975	USA	49	202	251	RTG
	USA	1	1	2	Red Brahman, Given to the King
	USA	63	84	147	Farmers
	USA	4	33	37	CP Ranch
1976	Aust.	2	29	31	RTG
	Aust.	8	13	21	Farmers
1977	USA	64	10	74	RTG
	USA	270	130	400	RTG/NELDP
1978	USA	22	58	80	RTG
Santa Gertrudis					
1966	USA			50	
?	USA			92	2 lots
Charolais					
1967	USA			15	
?	USA			33	

a. RTG = Royal Thai Government, DLA = Department of Local Administration, KU = Kasetsart University, NELDP = Northeast Livestock Development Project.

Table 5. Growth characteristics of indigenous Brahman, Zebu, and crossbreds (Yodseranee 1963).

Items	Breeds[a]				
	B	BT	Z	ZT	T
Number					
Male	9	8	13	7	18
Female	13	8	10	11	18
Birth weight (kg)	29.7	21.1	21.9	18.4	16.4
205 d. weight	192.4	139.2	148.3	123.0	119.3
Pre-weaning gain	0.79	0.57	0.72	0.51	0.51
21 m. weight	288.8	249.3	232.2	215.7	203.6

a. B = Brahman, BT = Brahman x Thai, Z = Zebu, ZT = Zebu x Thai, T = Thai indigenous.

Very small differences were found for 8 month weight and pre-weaning gain among Red Sindhi, Hereford, and Charolais sires. Tumwasorn *et al.* (1982) presented further results from crossbreeding of indigenous cattle with Brahman and Charolais (Table 7) to indicate a slight improvement in body weights in the Charolais cross over the Brahman cross from birth to over 60 months of age.

With these and a few other studies, as well as the results obtained by village farmers as judged by (1) adaptability to hot climate in Thailand, (2) resistance to some infectious diseases and parasites, (3) growing ability, (4) reproductive traits, and (5) farmer acceptability for draught, it was finally concluded that the Brahman breed is most suitable for beef breeding improvement on the national scale. However, it was observed also that further improvement in meat production could be obtained by using one of the other breeds such as Charolais in the crossbreeding program, if and when necessary.

Selection of Indigenous Cattle

Except for the data reported in Table 3, very little has been done to study the breeding performance of the Thai indigenous cattle. Most work was directed

Table 6. Growth of indigenous and crossbreds (Chantalakhana *et al.* 1971).

Sire[a]	Dam breeds[b]			
	RSX	ZX	T	Combined
Birth weight (kg)				
RS	20.6(35)*	21.4(10)	16.3(35)	18.7(80)
H	20.6(23)	21.0(13)	17.3(13)	20.3(49)
C	29.4(4)	19.3(2)	18.4(4)	19.4(10)
Combined	20.9(62)	20.6(25)	16.7(52)	
8 m. weight				
RS	106.2(25)	109.1(8)	102.5(27)	105.0(61)
H	118.8(19)	118.0(11)	102.3(12)	113.9(42)
C	123.9(2)	129.6(1)	98.2(4)	110.1(7)
Combined	112.2(46)	114.7(21)	102.1(43)	
Pre-weaning gain				
RS	0.36(35)	0.37(9)	0.36(26)	0.36(60)
H	0.41(19)	0.40(11)	0.35(12)	0.39(42)
C	0.44(2)	0.45(1)	0.34(4)	0.38(7)
Combined	0.39(46)	0.39(21)	0.36(42)	

a. RS = Red Sindhi, H = Hereford, C = Charolais.
b. RSX = Red Sindhi cross, ZX = Zebu cross,
T = indigenous cattle.
*No. of animals in parenthesis.

Table 7. Weights at various ages of indigenous and crossbreds (Tumwasorn 1982).

Breeds	Age (months)				
	Birth	7	12	18	> 60
Indigenous (I)	15.5	88.0	117.3	126.9	281.1
Brahman-I	19.9	101.2	130.8	156.7	381.4
Charolais-I	21.3	119.6	147.1	187.3	430.7

toward crossbreeding as presented in the previous section. No genetic selection or performance testing has ever been conducted in Thailand in spite of the substantial variation existing in various traits of the indigenous cattle. It is definitely very useful to carry out genetic evaluation of these animals. In addition, extensive research work concerning their productivity in comparison with larger breeds should also be conducted under small-farm production conditions, as well as under different management and feeding regimes.

Buffalo Breeding

There was practically no well-planned buffalo breeding work in Thailand before 1975 when the Department of Livestock Development, (DLD), Kasetsart University (KU), Khon Kaen University, the Office of Northeast Agriculture, and the Rockefeller Foundation (USA) signed a memorandum of agreement to conduct a joint research program for improvement of swamp buffalo production. The National Buffalo Breeding Centre at Surin Province has been organized, and buffalo performance testing has been conducted at the Lumphyakhlang Testing Station (Nokorn Ratchasima Province) through the joint efforts of the DLD and KU. Based on these early works, presently the National Buffalo Research and Development Centre Project has been organized, based on resources already existing in the DLD and other cooperating agencies and institutions, including Chulalongkorn University, Chiang Mai University, Maejo Institute of Agricultural Technology, Surin Agricultural College, and Prince of Songkhla University.

The Thai Indigenous Swamp Buffalo

Table 8 shows various characteristics of the Thai swamp buffalo under the prevailing low level of feeding and management in Thailand. Age at first calving of the swamp buffalo was found on average to be between 4.5 and 5.5 years. The calf crop under village conditions was reported at 35-40%, with a calving interval of 1.5 years (Chantalakhana 1983b). Seven-month weight averaged around 98 kg, mature weight (over 5 years of age) for females 360-440 kg, for males 520-560 kg, with pre-and postweaning gains of 340, and 340 to 650 gm, respectively.

Selection and Performance Testing

Breeding Program in Thailand. One hundred and fifty buffalo cows and 10 bulls were selected on body weight and conformation for breeding purposes. Single-sire breeding herds of 1 bull to 25 cows were used in two breeding seasons (January to March, and August to October) at the Surin Buffalo Breeding Centre. Later a ratio of one bull to 15-20 cows was used in order to improve calving rates.

All feeding and management were kept uniform

Table 8. Various characteristics of swamp buffalo (Chantalakhana 1983b).

Traits	Unit	Estimates
Birth		
weight (W)	kg	26.5 (23-28)
Heart girth (G)	cm	71.1 (M), 70.3 (F)
Body length (L)	cm	55.5 (M), 54.5 (F)
Height (H)	cm	67.7 (M), 67.2 (F)
7 month		
W	kg	98.4
G	cm	114.7 (M), 113.5 (F)
L	cm	85.0 (M), 83.2 (F)
H	cm	92.6 (M), 91.7 (F)
Mature		
W	kg	520-560 (M), 360-440 (F)
G	cm	170-210
L	cm	130-147
H	cm	120-138
Ave. daily gain		
Pre-weaning	gm	340
Post-weaning	gm	340-650
Carcass		
Dressing percent	%	42-49
Hide	%	12.5
Bone	%	20-23
Loin eye area	cm^2	41-43
Cold shrinkage	%	3-4.5
Milk		
Yield	L/d	1-3
Butterfat	%	8.3-10
Physiological Characters		
Respiration	/min.	30.7 (Noon), 30.9 (p.m.)
Pulse rate	/min.	49.7 (Noon), 56.3 (p.m.)
Body temp.	°C	38.4 (Noon), 39.1 (p.m.)

M = male, F = female.

for all animals during each season of the year. Pasture and silage were basic feeds, while feed supplements for cows were given only during the dry season to avoid nutritional stress.

The traits measured as the criteria of selection are: weaning weight (at 8 months) and measurements (heartgirth, height, and length) as well as pre-weaning growth rate. Selection was conducted for both male and female calves. All female calves were dehorned but the males were not, because farmers prefer breeding or work animals with nice looking horns.

The calves of both sexes were selected according to weaning weight, pre-weaning gain, as well as height and general conformation. Only 10 animals of each sex will be selected for performance testing. Selected individuals for the test will have to weigh 150 kg for males, and 140 kg for females at 240 days of age.

The selected animals, both male and female, were sent to another station for performance testing, due to limited facilities at the Surin Breeding Station. They were on test for one year. Again, feeding was based on grazing in pasture, but a cheap supplement consisting of cassava chips and leucaena leaf meal 3:1 by weight was given individually in the early morning before the animals went into pasture. Bone meal and salt (3:1) were given free-choice. It is the intention of this testing program to keep the level of feeding and management similar to that which can be provided by village farmers.

Weighing of the test animals was done once a month in order to closely observe the animals. The measurement of body height was conducted only at the initial and final weighing. Post-weaning gain was calculated. At the end of the one-year test period, selection of the animals on test was conducted by a committee, and was based on final weight, post-weaning gain, plus height, and general conformation.

All selected females were sent back to the Surin Station to be used as replacements, while the top bulls were used for AI, and the remainder of the selected bulls were used for other breeding purposes. A summary of results so far is shown in Table 9. This breeding program for improving size and growth in the swamp buffaloes in Thailand has been carried on since 1977, but the performance testing started only in 1981.

A summary of buffalo breeding at the Surin Buffalo Breeding Centre since 1976 is shown in Table 10.

Crossbreeding of Buffalo

Around 1955, a small number of Murrah buffaloes was introduced from Malaysia by the Kasetsart University for a milk production study. No crossbreeding experiment was conducted at that time. Some male buffaloes, however, were sold to dairy farmers for breeding with both Murrah and swamp buffaloes. This whole group of Murrah buffaloes was later sold to dairy farmers.

In December 1978, 100 Murrah buffaloes, (90 females and 10 males), were imported from India by the DLD for multiplication and crossbreeding with swamp buffalo. Most of these animals were kept at

Table 9. Results of performance test in swamp buffaloes in Thailand.

Items	Group 1		Group 2		Group 3		Group 4	
	M	F	M	F	M	F	M	F
No. of animals	10	10	10	10	10	10	10	10
Initial weight ± s.d.(kg)	186±21	203±18	160±17	161±13	156±29	170±10	170±24	179±16
Final weight ± s.d. (kg)	305±14	329±18	294±27	299±21	286±33	300±17	313±25	309±14
max.	335	355	337	333	346	314	362	328
min.	287	296	270	259	217	259	279	284
Ave. daily gain (gm)	326	344	363	373	355	355	382	351
max.	389	441	430	480	465	410	411	441
min.	279	279	296	298	273	265	324	268

For more details see 1982 Annual Report, National Buffalo Research and Development Center, Department of Livestock Development/Kasetsart University, Bangkok.

Table 10. Summary of Surin buffalo breeding from 1976-1983.

Traits	1976		1977		1978		1979		1980		1981			1982			1983		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
No. of cows	70	78	69	60	76	55	58	70	58	51	34	14	49	34	31	47	43	48	71
No. of bulls	3	3	3	3	4	4	4	4	4	4	2	1	3	2	2	3	3	3	4
Conception rate (%)	23	53	55	72	75	67	55	63	88	84	76	79	33	88	80	55	53	48	48
Calving rate (%)	17	46	54	67	61	80	50	60	79	71	56	57	31	82	81	40	53	*	*
No. aborted	4	5	1	4	13	3	3	1	1	0	3	1	0	0	0	7	0	*	*
Postnatal death	0	1	3	2	6	1	1	1	2	3	4	6	0	0	0	2	1	*	*
1st m. postnatal death	1	0	0	2	0	0	2	0	1	0	0	0	0	0	2	0	0	*	*

*Not available.

the Nong Kwang Livestock Breeding Station, Ratchburi Province (about 150 km from Bangkok). Some of them were later sent to a station in the southern part of Thailand for production study. Since 1979, some numbers of crossbreds have been born each year from swamp buffalo cows mated to Murrah bulls. The results so far obtained are summarized in Table 11. Average body weights of the Murrah and crossbred (half Murrah) were 22.6 and 29.2 kg at birth, 111.6 and 127.6 at 7 months, and 163.2 and 186.7 at 12 months, with pre-weaning average daily gains of 0.43 and 0.47 kg, and post-weaning gain of 0.34 and 0.39 kg, respectively. For milk production, Murrah buffaloes produced 3.36 liters (2.3-5.7) of milk per day with an average lactation length of 245 days (208-268). Feeding and management provided for all experimental animals was the same. No extra care was required by the Murrah, but the growth and size of the Murrah did not appear to be superior to the crossbred or the Thai swamp buffaloes.

Investigations on comparative performance including draughtability, of crossbreds and swamp buffaloes under different feeding regimes are now being conducted at the Surin Breeding Centre, in order to prove whether the crossbred buffalo is suitable and acceptable for draft-milk-meat purposes. If the results from this research are in favour of the crossbreds, then they will be evaluated under real village conditions to determine what additional feed requirements, both in quantity and quality, would be needed if crossbred buffalo were used simultaneously for work and milk (for home consumption), and whether village farmers could afford to provide the additional feed required without serious socio-economic drawbacks on other aspects

Table 11. Weights at various ages of crossbred buffaloes (DLD 1981).

Year	Birth		7 months		12 months	
	M	MT	M	MT	M	MT
1979	20.2 (68)	None	108.7 (61)	None	154.5 (58)	None
1980	24.6 (57)	26.9 (21)	109.3 (55)	117.4 (21)	151.1 (55)	186.7 (21)
1981	21.9 (18)	30.3 (21)	128.5 (18)	137.6 (21)	228.1 (18)	na
1982	27.7 (11)	30.6 (18)	na	na	na	na
Combined	22.6	29.2	111.6	127.5	163.2	186.7

M = Murrah; MT = Murrah half crossbred.
na = Not available when reported.

of an integrated farm production.

At this stage, crossbreeding of the Thai swamp buffalo to Murrah is limited to an experimental scale, until the above questions have been thoroughly investigated. In Thailand, it appears that much improvement can be achieved through breeding selection of the Thai swamp buffalo. There is no crossbreeding program for producing a new breed for Thailand at present since this would be too costly and genetically unnecessary.

Future Research Needs

It is obvious that breeding research in large ruminants in Thailand has been very limited, both in scope and size of experiment. Genetic information on the indigenous cattle and buffalo is seriously lacking. It is strongly recommended that a genetic evaluation scheme, to identify superior breeding stocks under well-defined environments for further multiplication and improvement, should receive highest priority and be carried out as soon as possible. Existing breeding and performance testing of the swamp buffalo needs to be expanded as much as possible (2 to 3 times) in order to increase selection intensity.

With current interest in the crossbreeding of cattle and buffalo with imported breeds in order to obtain dual- or triple-purpose animals, well-planned crossbreeding experiments are needed for a comprehensive evaluation of characters such as meat, milk, or draft, tick resistance, disease resistance, and the ability to utilize low-quality roughages, etc.

On a regional basis, it is recommended that an exchange of swamp buffalo germplasm resources for comparative evaluation among interested countries should be organized and supported by national or regional organizations.

Practical training for research personnel in animal breeding methods such as breeding herd management, data collection and processing, certain evaluation techniques, and other new techniques in animal genetics and breeding, is very necessary for a successful breeding research program.

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Improving the Swamp Buffalo of Southeast Asia

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AT present rates of increase, the human populations of most of the developing countries of SE Asia will double in the next 25 to 30 years and even if zero population growth (i.e. 2 children per family) were to be achieved immediately, populations would still more than double before they stabilized. Either scenario will create an unprecedented demand for food, and ultimately for renewable forms of energy for food production and distribution, and for domestic and industrial use. The requirement for food is such that it is absolutely imperative that domestic animals do not compete with humans for food. Present knowledge indicates that food production will continue to be based on cereals and that large ruminants will remain as a significant component of renewable energy supplies. Cereal production is likely to remain dependent on soil cultivation and to produce large amounts of fibrous residues that have limited use other than as low quality fodders that can be processed by ruminants into high quality food for humans. In some regions, cattle will be associated with cereal production but in other regions, sociological, topographical or climatic conditions will favour the use of swamp buffalo. If full use is to be made of the increasing amount of agricultural by-products produced in these regions and if the increasing demand for draught animal power is to be met, buffalo numbers will need to be increased. Similarly, if the swamp buffalo is to make an increased contribution to the standard of living of rural communities, its productivity, measured in terms of output of milk and meat, must also be increased. Some of the ways in which numbers and productivity could be increased are discussed in this article, which is based on a previous report to United Nations bodies (Frisch and Vercoe 1984).

Increases in Numbers

For food supplies to maintain equilibrium with human numbers, agricultural output must expand at a corresponding rate, and for the resulting increases in by-products to be efficiently utilized, buffalo numbers must be similarly increased. This implies a current rate of increase in numbers of from 2.5 to 3% per annum. However, swamp buffalo numbers are not keeping pace with human numbers, a failure that can be attributed to several causes, not the least of which are their low net reproductive rate and a rising demand for buffalo beef.

Annual calving rates at the national level have been reported to be from 33-65% (Bhannasiri 1980; Thamotharam 1982) and calf losses in the first 3 months after birth at from 20-40% (Bhannasiri 1980; Siriwardene *et al.* 1982). Perera *et al.* (1984) have estimated that the Lanka swamp buffalo has a lifespan of 20.5 years and produces 7.8 calves in that time. Of these calves, about 35% can be expected to die within one year (Siriwardene *et al.* 1982) with further mortalities after that time (Perera *et al.* 1984). Hence, net reproductive rate of cows is less than 25% per annum. This corresponds with the value for Thai swamp buffalo cows, which have been reported to have a national annual calving rate of about 34% and a mortality to one year of about 30% (Bhannasiri 1980). Given a net reproductive rate of 25% p.a., age at first calving of 4 years, a life span of 20 years and a sex ratio in the herd of 1 male : 2 females (Niumsup and Songprasert 1979), about 40% of the herd are expected to be females of breeding age. Thus, in the Thai national herd, which was reported to be about 5.4 million in 1978 (Bhannasiri 1980), about 2.2 million are breeding cows that can be expected to produce a net increase of about 540 000 calves per year. This is below the number of buffalo slaughtered in Thailand in 1978 by about 120 000 and hence the buffalo population can be expected to decline if for no other reason than as a direct result of an increased demand for beef. The actual decline in numbers reported by Bhannasiri (1980) was 110 000 per annum from 1973-1978. The rate of decrease in the buffalo population in Indonesia has been reported as about 1.3% p.a. (Toelihere 1980). These rates of decrease serve to illustrate the

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urgent need for an increase in net reproductive rate if the rising demand for both beef and draught in SE Asia is to be met from local resources.

Part of the increase in net reproductive rate must come from a reduction in mortality of calves. Mortality is generally associated with internal parasitism (mainly *Toxacara vitulorum*) and diseases (mainly rinderpest and haemorrhagic septicaemia -HS). Siriwardene *et al.* (1982) have partitioned the estimated 35% mortality in calves in Sri Lanka as 70% due to *T. vitulorum* and 30% due to HS.

In the absence of any known breeds or strains of buffalo that are innately resistant to infestation by *T. vitulorum*, chemotherapy offers the only practical means of control. Infestations can be eliminated by a single oral dose of levamisole and other anthelmintics (Sukhapesna 1978) and because of the short infective period, (Fernando *et al.* 1981), calves remain free of further infestation (Sukhapesna 1978). The single dose regimen is unlikely to lead to the development of resistance by the parasite to the anthelmintic within the foreseeable future and is so effective and cost efficient that chemotherapy is at present the only form of control that can be considered to have practical application.

Likewise, vaccination is the method of choice for control of HS (Bakar 1980; de Alwis and Wickermasinghe 1980) and where the combination of vaccination and deworming has been used, calf mortality has been reduced to about 8%, or less than 25% of the national average (Thamotharam 1982; Usanakornkul 1981). However, neither vaccination against HS (de Alwis 1982) nor deworming (Guzman 1980; Chantalakhana 1980) are widespread practices throughout the region.

The major limitations to improvements in calf survival are then mainly sociological or political rather than technological, and as well as directing effort toward the establishment of appropriate treatment regimes, some attempt should be made towards determining why existing technology is not, or cannot be, adopted. Perhaps the ban on slaughter of buffaloes under about 12 years of age acts as a disincentive to further increases in numbers — why should a farmer devote so much time and effort to rearing an animal that may die before it reaches slaughter age or on which he may not be able to realize his capital outlay when needed?

Improvements in reproductive rate are complex, for unlike mortality, the prime causes of low reproductive rate are not only environmental but also genetic in origin. The low reproductive rate of the buffalo is manifested through poor semen quality and lack of libido of bulls (Wierzbowski *et al.* 1980), and late age at first calving and long intercalving intervals of cows. Age at first calving under extensive farm conditions may be as low as 3.5 years (Perera 1981) but may extend beyond 6 years even at research stations (Usanakornkul *et al.* 1978). Intercalving intervals often exceed 3 years (Perera *et al.* 1982; Usanakornkul *et al.* 1978) and are seldom below 460 days (Perera 1981; Thamotharam 1982; Jainudeen *et al.* 1981).

These three characteristics of swamp buffalo fertility must be considered when improvements in reproductive rate are sought. However, a reduction in age at first calving of about 180 days, which is large in itself, is insignificant when compared with the cumulative effect of reducing each intercalving interval by the same amount. Likewise, the problems of poor semen quality and low libido of bulls are likely to be less of a problem once widespread and efficient AI services are established. The provision of these services is widely recognized in the countries of the region and is likely to become more important as increasing pressure on land forces an increasing proportion of buffaloes into a stall feeding situation.

The greatest scope for increasing reproductive rate is then likely to be related to a reduction in intercalving intervals of lactating cows. As in cattle, intercalving intervals could be reduced by feeding lactating buffalo cows on a high plane of nutrition. However, given the ever decreasing amount of land available for green forage production and the unlikely possibility that large amounts of concentrate feeds will ever become available for feeding buffaloes, it is unrealistic to expect that such an approach can ever be adopted at the national level. There is also the consideration that even with improved feeding (Usanakornkul *et al.* 1978; Jainudeen *et al.* 1984) intercalving intervals are still about 570 days. This represents the genetically determined average rate of calving of cows that are otherwise not restricted in expressing their inherent reproductive rate. Perera *et al.* (1982) have shown for river buffaloes and Jainudeen *et al.* (1984) have reported for swamp buffaloes that the long intercalving intervals are due mainly to delayed resumption of ovarian activity and that conception can occur as soon as ovarian activity recommences. Jainudeen *et al.* (1984) have reported that delayed activity is at least partly related to the suckling stimulus and that in these cases the combination of temporary weaning and hormone therapy of the buffalo cow to induce ovulation offers distinct possibilities for reducing the intercalving interval. Pregnancy rates in his experimental animals were however only 19% (4/21) and further refinement of the technique is required before it has practical application. The possibility also exists that, although hormone therapy may induce early ovulation, the cow may be incapable of conceiving or maintaining pregnancy at that time because of other physiological limitations. However, the system has great potential benefits, particularly when used in conjunction with AI; it offers a means for overcoming both the difficulty of oestrus detection, especially in cows that are continuously tethered, and a lack of bulls in those herds where there are only one or two animals.

Whilst such a system, if it were shown to be effective in reducing intercalving intervals, could be implemented at the village level, its merits must be weighed against the long-term advantage of using a buffalo breed that was sufficiently fertile to meet reproductive requirements with a minimum of human interference. What must be decided for each particular region and system of farming is what rate of reproduction is required to satisfy demands. Effort can then be directed at achieving a reproductive rate that will match the system of production and availability of resources, for nothing can be gained if feed supplies are insufficient to support extra animals or if extra animals are not wanted. This is particularly so if cows are to gain widespread acceptance as draught animals. Timing of pregnancy and lactation will be critical and for this system to be satisfactory, effort must be directed at the development of techniques (including feed supplementation, improved methods of oestrus detection or synchronization, improvement of AI methods and hormone therapy to induce a fertile oestrus) to ensure pregnancy at any nominated time.

Equally important will be an increasing requirement for cows to be able to conceive readily on straw-based diets. There is a pressing need to determine the critical levels of dietary supplementation and perhaps hormonal augmentation that are necessary to achieve satisfactory calving rates on these diets, and whether there is genetic variation in the ability of cows to calve regularly under these conditions. The levels of supplementation necessary to ensure the desired calving rate will determine whether supplementation alone will provide the solution or whether genetic improvement is also necessary.

Whilst there are reasons for believing that inherent fertility of the swamp breed could be improved by within breed selection (Frisch and Vercoe 1984), the facilities are not presently available to allow this avenue to be researched. There are however greater prospects for the identification of strains or breeds that have high calving rates for whatever reason. Perera *et al.* (1984) have drawn attention to the presence of village herds of Lanka buffaloes that have high realized fertility (mean calving interval of 394 $\pm$ 80 days) and to the possibility that the high fertility may be genetic in origin. It is imperative that these sorts of occurrences be thoroughly investigated, for if the herds have high inherent fertility they should be multiplied and disseminated. If their high fertility is of environmental origin, the reasons could be isolated and perhaps used in the environmental improvement of fertility in other areas. It is also likely that late age at first calving, poor bull performance, and long intercalving intervals of cows are all part of the same syndrome, and that genetic improvement of any of these characteristics will result in a corresponding improvement in the others.

Another avenue available for increasing net reproductive rate is to reduce the number of cows that are pregnant at slaughter. Fletcher (1984) and Eusebio (1984) have reported that 42% and 25% of cows in Java and the Philippines respectively were pregnant at slaughter. This anomaly should not be technically insurmountable if the desire for correction exists.

Several of the diseases that affect reproduction of buffaloes including vibriosis, brucellosis, and leptospirosis are all controllable by vaccination and other methods of control are not considered to warrant major research.

Improvement of Milk Yield

Those SE Asian countries where swamp (rather than river) buffaloes are reared, import almost all of their requirements for dairy products, and outlay substantial sums of hard currency that could be more profitably used for other commodities. The potential exists to satisfy at least part of the demand for dairy products from local resources (as is done in the Indian subcontinent), and the swamp buffalo could be used as part of the basis of this industry. However, the genetic potential for milk yield of the swamp buffalo is low (about 1-2 kg/day) and regardless of environmental conditions cannot be greatly increased. Potential yields can be at least trebled by crossing to a recognized dairy breed (e.g. Murrah, Surti) and, where feed resources are sufficient and other conditions suitable, a tenfold increase can be achieved by upgrading to the dairy breed. The optimum proportion of dairy breed in the crossbred animal will depend on environmental conditions, particularly feed supply, and other uses of the crossbred animals; the appropriate proportion needs to be determined for each particular set of circumstances.

Since there is genetic variation between the river breeds in both mature size and absolute milk yield, effort should be directed towards the identification of the most suitable breed for crossing to the swamp buffalo in each of these circumstances. There is a real need for comparative evaluation of the river breeds for the ability to produce milk on the sorts of diets available at the village level. In the medium term, these breeds could then be used for crossing to the swamp breeds, though, in the interim, the decision as to which breed to use in the cross could be based on considerations of differences in size and total milk yield of the available river breeds.

Whilst the technology for increasing potential milk yield is known, appropriate systems for making the most efficient use of limited feed resources need to be developed.

Increases in Draught Output

Unless a radical change in land tenure occurs in SE Asia, farm size is more likely to decrease than to increase. Under these circumstances the optimum size and hence draught capacity of animals required to work those farms will be largely determined by the availability of feed resources. It is therefore likely that a range of sizes of draught animals will be required throughout the region. The only means presently available for increasing the inherent draught capacity is to increase live weight since, for any given set of conditions, live weight is the main determinant of draught output (FAO, 1966 cited by Cockrill 1974; Liu 1978, cited by Chantalakhana 1980). The only practical means for increasing live weight is to cross to a breed of large mature size. Since their potential milk yield is also high, the river breeds are favoured candidates.

Heat tolerance has an important effect on working ability and research effort aimed at identifying the most heat tolerant of the candidate breeds could provide long-term benefits: draught capacity could be increased by increasing heat tolerance rather than by increasing live weight and hence, feed requirements.

Another avenue, which if feasible has obvious benefits, is the widespread use of cows for draught. Goe (1983) has drawn attention to the additional information needed to determine the feasibility of this practice at present levels of management. In the long-term, genetic improvement of cows simultaneously for both draught and milk provides an ideal solution. Na Phuket (1980) has calculated that replacement of two males by three females would not decrease draught output but could increase production capacity at the Thai village level by at least 40%. However, he also noted that a likely limitation to this sort of strategy was the extra requirement for feed.

An area that is worthy of further research is the development of improved harnesses and equipment, preferably from locally available materials. It has been reported (Anon 1981) that, if experimental results are indicative of general results, draught power at the national level could be increased by about 25% by the adoption of improved harnesses, without any need to increase the draught capacity of the animals.

Improvement of Growth Rate

Increases in absolute capacity to grow may become important in those few cases where swamp buffaloes are to be used solely for beef production. However, the main requirement will be to improve growth, and hence other attributes related to growth rate, on the sorts of diets expected to be available in the future, and these are likely to be increasingly based on straws and milling offals (Jackson 1981). Significant short-term improvements in growth can be expected from straw treatment and NPN supplementation enhanced by the addition of catalytic amounts of protected protein (Perdok 1984; Leng and Preston 1984).

Further long-term improvements are then dependent on the use of genotypes that can utilize these poor quality diets most efficiently, both for maintenance and growth. Differences may already exist between buffalo breeds, but there are no reported studies from which to determine the magnitude of the genetic variation in the efficiency of maintenance or growth on straw-based diets. This sort of information is required if long-term improvements are to be made and, since it is unlikely to come from temperate areas, will have to be initiated in the tropics where both the breeds and diets are available. It implies a detailed comparative evaluation, initially of different buffalo breeds and ultimately of different animals within a breed, for the ability to grow and produce on straw-based diets.

There is a need to consider the effects of major diseases when contemplating improvements in growth. Some of these diseases, including foot-and-mouth (FMD) and rinderpest, can be controlled by vaccination and should not be considered as insurmountable technical constraints to growth. Internal parasites are more difficult to control. However, with the exception of *T. vitulorum,* the pathogenicity of gastro-intestinal nematodes is reportedly low (Usanakornkul and Sukhapesna 1980). Thus, although they may depress growth, the cost of continual treatment necessary for their control is likely to be economically unjustifiable.

Two possible avenues to control their effects are the development of vaccines and the search for substantial genetic variation in resistance to gastro-intestinal helminths that could be further enhanced by selection for resistance. Although the former will be heavily dependent on advances in vaccine development outside of SE Asia, the latter would need to be researched within SE Asia itself. Besides depressing growth *Fasciola gigantica* causes adult mortalities, at least in some areas (Usanakornkul and Sukhapesna 1980). Effective treatment regimes are already known but since treatment must be continual and is relatively expensive, their widespread usage is unlikely to be adopted. There is no evidence for the existence of animals that are highly resistant to infection by, or the effects of, *F. gigantica,* but this may be because such evidence has not been sought. Another possible long-term solution that is worthy of investigation is the development of a vaccine against *F. gigantica.*

The Implementation of Genetic Improvement

The most efficient improvement of the productivity of the swamp buffalo will come from the simultaneous implementation of both environmental and genetic modifications, i.e. matching the animal to whatever environment is economically attainable. Ultimately, this is dependent on the use of within-breed selection to obtain the appropriate combination of characters for any given environment. However, in the short-term the rates of progress likely to be achieved by within-breed selection are too low to keep pace with increases in human populations, and in consequence, no immediate increase in the amount of animal product per person can be achieved. Small herd size, low net reproductive rates, extreme variability of environmental and managerial conditions, and lack of recording equipment all mitigate against the achievement of any significant genetic progress at the village level. Within-breed selection is then feasible only in large, well organized, well documented herds such as those attached to research centres, or where efficient AI programs can be organized to allow contemporary comparisons of buffalo sires over large numbers of village cows.

For progress to be made through AI, simple but accurate systems would have to be devised to measure progeny of the different sires particularly for such characters as the ability to grow and reproduce on the types of diets available at the village level. Net reproductive rates must also be increased to provide sufficient numbers of animals to allow selection to be effective. Both requirements present real challenges. The widespread dissemination of bulls identified at the research centre as being superior to their contemporaries is dependent on an efficient AI program. Equally important, the rate of genetic gain at the village level is also dependent on selection at the research centre being performed on diets similar to those that exist at the village level. There can be no genetic progress at the village level if selection for increased productivity at the research centre depends for its expression on high quality diets that are unattainable at the village level.

Because of the difficulties confronting any attempt at within-breed selection, every effort should be made to maximize rates of genetic progress by crossbreeding before embarking on any long-term attempt to improve productivity by within-breed selection. There is considerable scope for the identification of the most suitable breeds to use in a crossbreeding system. The races of buffalo from SE Asia, Europe, and the mediterranean region have been separated for centuries and have evolved along different pathways. They can be expected to have different maturation rates, milk yield/unit of live weight, mature size, and resistance to environmental stresses. Crosses of the different races can be expected to have different levels of productivity and to express different amounts of heterosis. They may also have impaired reproductive rate because of the different karyotypes of the parental breeds. There are however no documented accounts of the comparative performance of any of these races from which to make assessments of the likely benefits from crossing any particular pair of races.

Any scheme for genetic improvement must bear in mind the limitations set by the plane of nutrition. In most regions, cereal straws and by-products must remain as the main feed resources of the swamp buffalo. These diets cannot support high levels of production, and although straw treatment or the addition of NPN or protected protein can increase the value of the diet from submaintenance to a point where production can be achieved, it is unrealistic to expect that western levels of production can ever be achieved. This has complications for the direction of research effort aimed at increasing productivity.

Western systems of genetic improvement of domestic animals have concentrated on increasing genetic potential and modifying the environment to allow maximum expression of this potential. However, under SE Asian conditions, there can be no benefit from crossbreeding or selection programs directed at the genetic improvement of production potential of the swamp buffalo if the increase in potential cannot be expressed because of a low plane of nutrition. Effort would be better directed towards finding ways of breeding swamp buffaloes that are efficient at using the existing diets and towards improving these diets rather than trying to breed animals that have high productivity but only on high quality diets. Whatever system is used, the gains must be sustainable without the need for ever-increasing amounts of high quality concentrate feeds that are so often imported and which can be used more efficiently for other purposes.

Thus, although some of the technology for increasing the productivity of the swamp buffalo is known, some remains to be devised. Whether this could best be done with existing resources or by following the pattern set by the International Research Centres and establishing a centralized improvement centre for the swamp buffalo remains to be determined. In the meantime, every effort should be made to implement the existing knowledge, for it is only in that way that the swamp buffalo can continue to maintain its contribution to the rural economy of SE Asia.

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Cattle Evaluation Studies and Future Priorities in Malaysia

S. Sivarajasingam*

CATTLE numbers and quality are critical factors that have impeded the rapid development of the local beef and dairy industries especially in the light of increasing demand for meat and milk. The high humidity (65-97%) and environmental temperatures (22-33 °C) are also important climatic constraints. In 1980 Peninsular Malaysia was only 45% self-sufficient for beef and 3% for milk with a population of 481 500 cattle and 199 500 buffaloes, and a human population of 11 352 100. The human population is increasing at 2.3% while extraction rate for cattle is 17.7%.

This situation had been realized for many years and the government had initiated extensive cattle development programs during the last two decades. The indigenous Kedah Kelantan (KK) cattle, which constitute 80% of the cattle population, are used for beef and draught power like the buffaloes. The Local Indian Dairy (LID) cattle, derived from various *Bos indicus* breeds of Indian origin, produce the bulk of the fluid milk and have a significant beef potential. With the objective of producing more beef and milk, the Division of Veterinary Services (DVS) carried out extensive crossbreeding using Red Sindhi and Sahiwal in the fifties and Friesian, Jersey, and Australian Illawarra Shorthorn (AIS) for milk, and Brahman, Angus, Hereford, Charolais, and Droughtmaster (just to name a few) for beef since the sixties. There are now about 20 000 head of dairy crosses in the country. However, there was no sign of local production increasing at the same rate as demand. This was because of our small cattle population and the total lack of a coordinated national breeding program complete with a recording system, locally tested bull semen, and a system of 'weeding' inferior animals.

Currently only about 2-3% of the national herd is under artificial insemination. Thus, the alternative was to import the desired crossbreds. Since 1979 the Division of Veterinary Services has imported over 18 000 head of Sahiwal Friesian F_1 crossbreds from Australia and New Zealand. Other breeds such as Droughtmaster (6225 head), Brahman (2880), Santa Gertrudis (623), and small numbers of AMZ (Australian Milking Zebu) and Friesian were also imported from Australia. Cattle breeding including evaluation and selection is one of the major areas of research of the Division of Animal Production of the Malaysian Agricultural Research and Development Institute (MARDI).

It is now clear that the quickest way to achieve high levels of milk and beef among local cattle is by (a) crossing them with temperate breeds, and (b) providing them with an improved environment in terms of climate, feeding, management, and health. By crossbreeding we are introducing superior genes into the population and heterozygosity, the latter being the basis for hybrid vigour.

The next obvious question is what to do with the crossbreds. The answer is largely dependent on our long-term objectives and research results. The main alternatives are: (a) continuous production of F_1s if hybrid vigour is large enough to justify costs, (b) utilization of the combined advantages of superior genetic material and heterozygosity by producing grades by criss-crossing, and (c) evolution of a new breed by *inter se* matings with simultaneous selection of the F_1 or a grade, thus exploiting the effect of superior gene introduction.

Three important areas need to be researched before any decision can be made: first, which exotic breeds will give the most hybrid vigour and/or respond to intensive selection amongst the crosses under prevailing conditions; secondly, what are the magnitudes of hybrid vigour in the F_1s and the grades, and their response to environmental variations in village farms; third, the optimum level of exotic inheritance for alternatives (b) and (c) above.

Considerable work has been done on breed and crossbred evaluation. The performance of the KK, LID and crosses are reviewed. Future priorities are outlined in the light of possible Australian cooperation.

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The Kedah Kelantan Cattle

These indigenous animals are of Zebu ancestry having a well developed hump. They are hardy and well adapted, generally brown in colour with a mean height at withers of 102 cm (Devendra and Lee 1975). They are used for meat and draught, and found throughout Malaysia.

The growth and reproductive performance of KK cattle is summarized in Tables 1 and 2. The data show that the KK is a small animal compared with Brahman or other established beef breeds. In spite of the late first calving age, they drop a calf once every year.

Table 1. Growth performance of Kedah Kelantan cattle.

Trait	Means	Source
Weight at birth: males (kg)	14-16	a,d
females (kg)	13-15	a,d
Growth: birth to weaning (g/day)	259-332	b,d
Weaning weight: both sexes (kg)	61-73	b,d,e
Yearling weight: females (kg)	80-111	b,d,e
Growth: weaning to 24 mo (g/day)	339	b
Weight at 2 years (kg)	189-241	b,d
Mature weight: males (kg)	300-312	b,e
females (kg)	229-240	b,e
Weight at slaughter	201	b
Dressing %	45-55	b,c
Meat as a % of carcass	83	b
Meat:bone ratio	5.4 : 1.0	b

Source: a. Devendra *et al.* 1973; b. Devendra and Lee 1975; c. Pathmasingham 1975; d. Wolf *et al.* 1982; e. Dhalan *et al.* 1981.

Table 2. Reproductive performance of Kedah Kelantan cattle.

Trait	Means	Source
Age at first oestrus (mo)	10-12	b
Age at first conception (mo)	18	b
Weight at first conception (kg)	166	c
Age at first calving (mo)	27-44	b
First calving to conception (days)	81	c
Calving interval (days)	341-451	a,b,c
Conception rate (%)	80-95	b
Calf mortality (%)	5.5	b

Source: a. Devendra *et al.* 1973; b. Devendra and Lee 1975; c. Wolf *et al.* 1982.

The Local Indian Dairy Cattle

These animals, which are tall (about 120 cm at the withers), have a prominent hump, loose skin, and a conspicuous dewlap. They form a very heterogeneous population whose ancestors include Indo-Pakistan Zebu breeds such as Sahiwal, Red Sindhi, Ongole, Kangayam, and Halikar. Coat colour variation includes white, grey, and various shades of brown.

The LIDs are raised for milk production, mainly in the west coast of Malaysia. They are stray-grazed in herds of about 20 head over vast areas of poor 'pasture' with minimum supplementation. They yield about 500 kg of milk per lactation (Sivarajasingam and Kassim 1974). Under improved feeding and management (Sivarajasingam *et al.* 1974) their average milk yield was 941 kg (88% improvement). Milk yield, growth, and reproductive characteristics of LID are given in Tables 3 and 4. For beef characteristics they are comparable with the KK cattle. The mean fat percent of milk in LID was 4.28 (Sivarajasingam 1975a).

Data in Tables 1 to 4 indicate that the KK and LID are useful genetic resources that need further study, improvement, and conservation. They are highly

Table 3. Milk yield and growth characteristcs of Local Indian Dairy cattle.

Traits		Means
Milk yield (kg):	first lactation	898
	all lactations	502-941
Birth weight (kg):	males	20
	females	19
	adjusted	22
6-mo weight (kg):	males	87
	females	74
Yearling weight (kg):	males	163
	females	143
18-mo weight (kg):	males	225
	females	188
Adult weight (kg):	males	398
	females	330
ADG* (g/day) birth to 6 mo	male	320
	female	280
7 mo to 12 mo	male	520
	female	380
Meat : bone ratio	male	4.44 : 1
Dressing %	all sexes	49-52

*ADG = Average Daily Growth.
Source: Sivarajasingam *et al.* 1974; Sivarajasingam 1975a; Sivarajasingam 1982; Mukherjee *et al.* 1976; Sivarajasingam and Kumar 1984; Sivarajasingam and Kassim 1974.

Table 4. Reproductive performance of Local Indian Dairy cows.

Traits	Mean
First calving age (mo)	48.4
Age at peak yield (yr)	7.3
Lactation length (days)	230.0
Calving interval (days)	412.0
Conception rate (%)	54.6
Repeat breeders (%)	22.5
Anoestrus (%)	17.5
Calf mortality (%)	4.0
Lactation length (days)	249.0

Source: Sivarajasingam *et al.* 1974 and unpublished data 1972-1977.

tolerant to tick infestation, and adaptation studies on LID (Sivarajasingam 1975b) have recorded favourable observations. However, these animals have a poor temperament and milk letdown is affected in the absence of a calf at foot.

Exotic Pure and Crossbreds — Milk Production

Purebreds such as Red Sindhi, Jersey, Holstein-Friesian, Australian Illawarra Shorthorn, and Brown Swiss have all been imported from time to time and reared in government farms. None of them produced yields (Table 5) comparable with the yields in the country of origin. Mortality was high due to anaplasmosis or babesiosis and many were culled due to foot rot, wounds, mastitis; high veterinary costs were incurred. A pure bred herd of 46 Holstein Friesians giving an average of 18 kg/day/head (Sivarajasingam and Kassim 1974), was once owned by a commercial farm.

Crossbred data have also been published (Table 5). The Red Sindhi x LID crosses, probably because of the relatively close relationship to the parent breeds, did not show marked improvement comparable with that seen amongst the *Bos taurus* crosses. The published data in Table 5 tend to favour Friesian crosses over the other crosses, followed by the Australian Milking Zebu.

Exotic Pure and Crossbreds — Beef Production

MARDI, the Agricultural University of Malaysia (UPM), and DVS have all imported Brahman cattle from the United States and Australia. They have been maintained pure, as well as interbred with the KK. Their performance, together with that of Santa Gertrudis, Droughtmaster, and KK crosses to Angus, AIS, Brahman, and Hereford are presented in Table 6. The limited data show considerably higher growth rates amongst the Brahman and crossbreds, in particular the half-bred Brahman. In a recent study (Sivarajasingam and Pathmasingham 1978) it was shown that the quarter-*Bos taurus* (Angus and Shorthorn) were superior to the corresponding half- and three-quarter exotic crosses.

Preliminary results at MARDI station in Kluang showed that Brahman-KK F_1s had a higher (0.515 kg) pre-weaning daily gain than Hereford-KK F_1 (0.435), Friesian-KK F_1 (0.414) and purebred KK (0.312) calves of both sexes.

Exotic Pure and Crossbreds — Reproduction

Various aspects of reproduction have been studied. The most common measures are first calving age, calving interval and conception rate. These are presented in Table 7 together with calf mortality and

Table 5. Milk yield exotic and crossbred cattle.

Breed	Lactation/ age	Data analysis	Means (kg)	Source
Red Sindhi (RS)	1-5	2*	835	a
½ RS x ½ LID	1-5	2	862	a
¾ RS x ¼ LID	1-5	2	871	a
⅞ RS x ⅛ LID	1-5	2	854	a
Jersey (J)	NS	1	1165-1519	d
½ J x ½ LID	1	1	1189	g
½ J x ½ LID	1-3	1	1200	f
Friesian (F)	1	1	924-2171	c,h
½ F x ½ LID	1-5	2	2241-3474	i,b
½ F x ½ LID	1	1	1758	c
½ Sahiwal x ½ F	1	1	511-2771	e
¾ F x ¼ LID	1	1	1452	c
AMZ	NS	1	1248-1922	d, j
Australian Illawarra Shorthorn (AIS)	1	1	1256	h

*1 = raw average, 2 = statistically adjusted for environmental variations, NS = not stated.

Source: a. Sivarajasingam and Mukgerjee 1975; b. Sivarajasingam *et al.* 1974; c. Sivasupramaniam and Mahmud 1981; d. Sivasupramaniam *et al.* 1981; e. Unpublished data; f. Sivarajasingam 1982; g. Samuel 1973; h. Lingam *et al.* 1977; i. Sivarajasingam and Kumar 1984; j. Mak *et al.* 1978.

Table 6. Beef characteristics of exotic and crossbred cattle.

Trait		B	½B ½KK	½H ½KK	½A ½KK	½AIS ½KK	¼H ¾KK	¾H ¼KK	¼B ¾KK	SG	D
Birth wt:	male	28	19-20	21	15-25	14-26	22	23	20	25	
(kg)	female	24	18-19	19-21	14-24	17-25	18	21	20	24	
Yearling:	male	79	180	175	146	119	154	152	175	435 Adult	432 Adult
	female	85	160	124-162	131	120	124	140	141		
ADG (1 yr)	male	.51	.41-.48	.41	.34	.31	.36	.35	.42		
(kg/d): (1 yr)	female	.46	.30-.47	.38	.31	.27	.29	.33	.33		
Dressing %		44.8	56.2	52.0*							53.6
Meat : bone ratio		2.61	4.32	3.3*							2.21

B = Brahman
A = Angus
AIS = Australian Illawarra Shorthorn
KK = Kedah Kelantan
ADG = Average daily gain
SG = Santa Gertrudis
D = Droughtmaster
* 25-50% Hereford

Sources: Devendra *et al.* 1973; Pathmasingham 1975; Baharin and Mak 1975; Flint 1971; Mukherjee *et al.* 1976; Pathmasingham and Sivarajasingam 1978; Pathmasingham *et al.* 1981; Hilmi and Vidyadaran 1980.

lactation length. Data on calving percent are almost absent. Although there are distinct differences between breeds, within-breed variations are largely (about 80%) due to environmental factors. These factors include accuracy of heat detection, artificial insemination techniques, disease and nutritional status of cows, and degrees of protective measures from climatic stress.

The purebred and three-quarter Friesians tend to have a later first calving than the Friesian half breds. The same could also be said for the interval between calvings. The data also indicate that the beef crosses tended to have longer calving intervals than dairy crosses. However, this could be due more to differences in management systems. There is considerable variation in the calving intervals and in all cases, it exceeded one year. The Kedah Kelantan cattle under stall fed experiments (Devendra and Lee 1975) gave intervals of less than one year (Table 1). The mortality rates were significantly higher for exotic crosses (15-57%) than for LID (4%) or KK (6%).

Current Breed Evaluation Studies

MARDI is currently conducting breed evaluation studies involving dairy cattle at Serdang, and beef cattle at Kluang.

Dairy Bull Calf Selection

Comparative studies on Friesian-LID, Jersey-LID, Jersey, and LID calves include measurements on weight, body size, rectal temperatures, respiration rates, tick count, intestinal parasite egg count from faecal samples, and semen quality and quantity. The Friesian-LID and LID bulls will be progeny tested when sufficient frozen straws have been prepared.

Imported Sahiwal-Friesian

These crosses are being evaluated for milk yield performance and reproductive efficiency.

Crossbred Data

About 4000 edited data on dairy crossbreds have been compiled from Institute Haiwan. They are currently being evaluated statistically for breed differences (Jersey, Friesian, AIS), superiority of crossbreds, and factors affecting breed evaluation studies. Traits include birth weight, growth data, first lactation milk yield, reproductive efficiency, and the effect of foetus on milk yield among crosses.

Beef Cattle Crossbreeding

Kedah Kelantan cattle have been crossbred with

Table 7. Reproductive measures of exotic and crossbred cattle.

Animal	Age at first calving (mo)	Calving interval (days)	Insem-inations per con-ception (no)	Calf mortal-ity 0-12 mo (%)	Lact-ation length (days)
RS	50	522	2.17		230
F	30-36	388-530	2.0-3.1	42-57	121-221
J	—	374-423	2.2-4.3	23-39	285-300
AIS	—	—	—	—	237-290
AMZ	—	374-424	—	15-44	276
H	—	396-560	2-4	—	—
D	30	460	—	—	—
B	33	537	—	—	—
SG	47	594	—	—	—
½ RS x ½ LID	51	476	1.74	—	224
½ H x ½ KK	35	413	1.79	—	—
½ B x ½ KK	36	—	3.00	—	—
½ A x ½ KK	32	525	—	—	—
½ A x ½ LID	35	—	—	—	—
½ S x ½ KK	31	562	—	—	—
½ S x ½ LID	32	553	—	—	—
½ F x ½ LID	33	411-416	2.33	—	215
½ J x ½ LID	37	402	2.49	—	272
¾ H x ¼ KK	31	—	—	—	—
¾ F x ¼ LID	38	437	—	—	—
¾ J x ¼ LID	33	—	—	—	—
¼ B x ¾ KK	36	—	—	—	—

RS = Red Sindhi, F = Friesian, J = Jersey, AMZ = Australian Milking Zebu, LID = Local Indian Dairy, KK = Kedah Kelantan, B = Brahman, H = Hereford, A = Angus, S = Shorthorn, D = Droughtmaster, B = Brahman, SG = Santa Gertrudis, AIS = Australian Illawarra Shorthorn.

Source: Sivarajasingam *et al.* 1974; Sivasupramaniam *et al.* 1981; Lingam *et al.* 1977; Baharin 1977; Mak and Baharin 1975; Mak *et al.* 1978; Murugaiyah *et al.* 1983; Samuel 1974.

Friesian, Hereford, and Brahman. The crossbreds are compared with KK purebreds. Measurements on growth and carcass characteristics are being made on all four groups of animals.

Appendix 1 gives a summary of current joint projects in Malaysia with foreign agencies.

Shortcomings of Past Evaluation Studies

Statistical treatment of data in most of the publications has been limited to means and standard deviations only. By their nature, cattle breeding data cover numbers of years and, due to the extensive nature of the data, environmental factors play an important role in the variation of samples. Results need to be adjusted for these factors, together with others such as age, sex etc.

A distinction between documentation and evaluation needs to be made. The former, meaning collation of records on single breeds, strains or crosses, has little value for breed comparisons. Evaluation is the comparative performance of contemporary animals of different breeds, strains or crosses with set objectives. Relatively few such evaluations have been made. A number of publications reported on single breeds, and others compared two breed crosses without either of the parental breeds or a reference breed.

A common problem with cattle data is small sample size. Sampling errors may be critical in many of these reports. Some of them have as few as 10 observations per breed or crossbred group.

At present, traits for complete characterization of any one breed have to be gathered from a number of publications. These publications differ in sample size, location, management system, statistical treatment of data and also the nature (breeding methods, selection practised, etc) of the population used. Thus the overall performance (with underlying interrelationships between traits) of the animals so compiled need not necessarily represent the true total merit of the breed.

Genotype-environment interaction studies are also lacking. This is an important component of breed evaluation studies where ranking of breeds and crosses may be significantly altered in different environments. Degrees by which the effects of stressful environmental factors (heat, solar radiation, tick infestation etc.) have been reduced, have varied in the different publications. Such factors need to be documented, and their effects on the comparative performance of different genotypes evaluated. Most of the results are derived from a single farm. The comparisons in each publication should be made with data from a number of locations.

Considerable variation exists in the sampling of sire semen of various exotic breeds. The imported semen used in crossbreeding does not comparably represent each breed. For instance, progeny of average Friesian bulls may be compared with progeny of top Jersey bulls. In a number of studies progeny were derived from 2-3 bulls and compared with another cross derived from 15 bulls.

Cattle Disease Occurrences

Other than the tick resistance of *Bos indicus* breeds, which reduces the frequency of babesiosis and anaplasmosis, no other breed differences in disease or parasite resistance have been detected. Diseases causing death and poor performance of cattle throughout the country are haemorrhagic septicaemia, colibacillosis, pneumonia, salmonellosis, helminthiasis, and mastitis (mainly subclinical). Brucellosis, Johne's disease and Infectious Bovine Rhinotracheitis (IBR) are endemic, showing positive serological tests. Foot and mouth disease, since its last outbreak in 1982, is under control due to massive vaccination and strict quarantine procedures on imported animals. Internal parasitic diseases are mainly due to helminthiasis and fascioliasis. Preventive and control measures are confined to brucellosis, Johne's disease, tuberculosis, haemorrhagic septicemia, and tick-borne diseases.

Research Priorities for Breed Evaluation

It is conceivable that we have to evolve superior breeds to fit the stressful environment and farmers are expected to achieve better levels of feeding and management in the future. In April 1980 a national breeding policy for dairy and beef cattle was agreed upon by all government agencies involved in animal production. For dairy cattle, a 50% Friesian level of inheritance was recommended for average smallholders and criss-cross mating with not more than 62.5% Friesian inheritance for better farmers. For beef cattle, Hereford, Friesian, Brahman, and Droughtmaster breeds were recommended for crossing with the KK cattle. The decisions were based on past experiences although exhaustive research results were not available. Some of the priorities for research on breed evaluation, and other aspects of on-farm research priorities are:

1. Experiments to test for heterosis and/or complementarity, with the production of F_1, F_2 and backcross generations to be used for contemporary comparisons in different locations. This proposal had been pointed out by Mahadevan (1977) who also stressed that reproductive efficiency, viability, disease resistance, growth rate and final size are no less important than milk yield in dairy cattle. The same traits are applicable to beef cattle where selection is on weight and carcass characters.

2. Test the suitability of breed crosses under different (two or three) levels of management to determine the degree of adaptability of different breed crosses and levels of exotic inheritance. Knowledge of the kinds of adaptations required by typical classes of environments and the adaptations available in various breed crosses are required (Mahadevan 1977) for current and future breeding strategies. Experimental designs need to be outlined for such genotype-environment interactions.

3. Research that will define characters that will predict adaptation to the environment accurately, with guidelines to measure them. These measurements should be simple for field application. Of major concern are tick resistance, efficient heat loss mechanism (sweating rate), disease resistance, and heat tolerance.

4. Development of a national program for selection of dairy and beef sires is strongly emphasized. A recording system needs to be formulated for animal performance as well as environment characterization. A systems approach should be applied to select sires on total economic merit. Immediate attention could be concentrated on LID, KK, and Friesian halfbreds.

5. The LID and KK are important animal genetic resources that need to be conserved and improved. Characters for improvement (adaptation, reproductive efficiency and/or yield) need to be defined, and procedures for within-breed selection formulated for optimum genetic progress.

6. Find ways and means to increase the cattle population size in the country. The effective way is to supply superior bulls/semen and develop effective extension services.

7. The concept of farming system has been extensively talked about but very limited objective research has been attempted. This is an important area of animal production especially for smallholder livestock development. Considerable work in the various disciplines of animal production have been made in the past. Attempts to link them together should be made so that 'grey' areas could be identified and studied.

8. Besides the absence of suitable high-yielding genetic material, feed resources, directory of feed requirements, feed evaluation, and systems of feeding and management are also lacking. Research activities need to be stepped up in these areas. Large amounts of agricultural by-products, forage, and forage areas in plantations could be usefully utilized. MARDI is currently working in this area.

9. Another priority area is to reduce the high incidences of repeat breeders and anoestrus conditions in cattle. Low reproductive efficiency is on the increase especially amongst high-yielding dairy crossbred cattle. Disease, nutrition, and genetics should be integrated to study this problem.

How Australia Can Assist

Australian scientists and institutions could provide assistance in a number of ways:

1. Provide funding and staff at farm level to develop farm facilities and infrastructure for research in priority areas, especially in sire selection, crossbreeding, and development of breeds for dairy and beef production. The current project on sire selection initiated by MARDI needs to be implemented on a number of farms with DVS collaboration and these funds are necessary for infrastructure development. Testing the animals at smallholder level is possible but selection and crossbreeding for breed development on smallholder farms is presently limited due to their size and other factors.

2. Provide superior young bulls for use in Malaysia for further performance testing. Until more research results are available, the halfbred Friesian bulls are preferred.

3. Provide expert advice and facilities for identification of selection criteria and their techniques of measurement, especially in the area of tick resistance and sweating rates.

4. Provide facilities and expertise in embryo transfer techniques that will enable in particular the rapid multiplication of bulls superior for production and/or resistant to one or more environmental stresses.

5. Assist in the establishment of a microbial genetics and cytogenetics laboratory. The former facility will utilize genetically engineered ruminal bacteria to control digestion of specific feedstuffs and regulate the fermentation products, and to control specific bacterial species.

6. Provide short-term (3-6 months) facilities for Malaysian scientists to work with scientists in Australian institutions. This will allow exchange of ideas and adoption of new techniques in Malaysia. Training facilities in various research techniques are also required for support staff.

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Appendix 1

The following projects are with foreign agencies:

Animal Genetic Resource Data Bank

This is a project between UPM and FAO coordinated by the author. It was initiated in September 1982. It involves the collection of data on all breeds of livestock and their environments, into a system of formats that is now being developed. Duration of the study is one year.

AMZ Progeny Testing

This was started in 1981 between the National Livestock Development Cooperation (MAJUTERNAK, which is now absorbed into the DVS) and CSIRO, Australia. This project involves the testing of AMZ bull progeny in Australia and on a farm in Malaysia for the benefit of AMZ breeders and the DVS. The latter will be provided with the top quality bull semen tested both in Malaysia and Australia. The program will continue indefinitely.

Malaysian-German GTZ Program

This was started in 1967 between Germany and DVS. The project involves (a) animal health, (b) training of laboratory technologists, (c) establishment of a data bank, and (d) dairy development projects in the field. The project was initiated in phases, the last ending in 1986.

Tropical Agricultural Research Center (TARC, Japan)

This linkage between MARDI and TARC was started in 1978. Japanese scientists are successively attached to MARDI, each for a 2 year period to undertake research on some aspects of animal nutrition of mutual interest for MARDI and TARC. Until now two Japanese scientists have worked in MARDI and returned. A third scientist has started his assignment in the area of buffalo and cattle nutrition.

Selection within Crossbred Populations for Cattle Improvement in the Tropics

I.R. Franklin*

THIS paper discusses the design of cattle breeding programs for hot, humid climates. In formulating breeding plans we are constantly reminded of the need for compromise in the development of objectives. First, and above all, we must seek a compromise between production and adaptation. Also, we must strike a balance between long-and short-term gains, between the exploitation of heterosis and the use of additive genetic variance, between body size and feed availability. There may be a conflict in the needs of dairy and beef enterprises. The view that objectives can be antagonistic is deeply rooted in the thinking of the Rockhampton laboratory, but I wish to develop it from a slightly different point of view: that of a geneticist rather than a physiologist.

Cattle are very important to the tropics. Approximately half of the world's cattle reside in these zones. There is a prevailing attitude, perhaps unwarranted, that production from cattle is inherently more efficient in temperate zones. This view seems to be held by most economists and politicians, and by many agricultural scientists in developed and in developing countries. There are certainly deficiencies in the nutritive value of tropical pastures. There is no doubt that tropical breeds do not have the 'production potential' of temperate breeds when measured in terms appropriate to temperate agriculture. However, it is difficult to believe that temperate breeds are much more advanced in an animal breeding sense than their tropical counterparts; as Cunningham (1979) has pointed out modern selection techniques as applied to cattle are a very recent phenomenon.

The 'inefficiencies' of tropical cattle production are aggravated by the continued advocacy for the tropics of breeds and management systems designed for temperate agriculture. Producers in the tropics are constantly reminded of the high yields attained in Europe or North America and, against these, local production can look pitiful. Comparisons of this kind are not only odious but can be very misleading. Take, for example, milk production under intensive management in North America versus that from extensive conditions in subtropical Australia. Here the differences in average production may be as much as 5000 litres per lactation, say 2500 litres versus 7500. One would be inclined to say at first sight that the North American industry is more 'efficient'. However, if one looks at the return to the farmer for an average dairy operation, or the price of milk to the consumer, there is almost no difference between the two industries. It is pointless to draw comparisons between the two production systems; they are simply different but perfectly matched to their own environments. If the cost of concentrates increases faster than the costs of beef or milk, we may even see a reversal of the trend towards intensive enterprises and a return to extensive production on our less arable grasslands.

The economic success of a production system must be judged by an analysis of returns and costs at the herd level, not on production figures from individual animals. Similarly our breeding objectives must be determined by such considerations (Cartwright 1982). Only then we may free ourselves of the current obsession with attempting to breed larger and larger animals with higher and higher production per beast. In the tropics such a policy could be disastrous; in these environments the strategy must be one of optimization rather than maximization.

Crossbreeding versus New Breed Development

Compared with other domestic animals and plants, cattle have a low fecundity. For this reason one cannot develop a stable industry based predominantly on crossbreds. Purebreds of both parental strains need to be maintained in substantial numbers, and, furthermore, both parental strains must be productive. This is a problem if we wish to exploit the very substantial hybrid vigour associated with *Bos taurus* by *Bos indicus* crosses. It is clear that in the long term we must direct our attention to the development of new breeds that are both adapted and productive.

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One of the major problems with the evaluation of crossbreds is the time and manpower consumed in estimating small differences between various breed combinations. From a long-term point of view, if we agree that the development of a stabilized breed is desirable, it makes little sense putting a lot of effort into deciding that, say a Hereford by Brahman cross is 5% better than an Angus x Brahman, or that Jersey x Hariana is 8% better than a Brown Swiss x Gir in a particular environment. If the traits involved have a reasonable heritability, such small differences can be made up quite rapidly, given a well designed breeding program. In addition, these statistics tell us very little about the general combining abilities of the breeds involved.

If the goal is to develop a new breed, then it seems to me that the best strategy is also the simplest, namely that semen be imported from a number of sources for each of a reasonable range of breeds, that these be crossed into the indigenous adapted population, and that the selection process be allowed to sift the desirable elements from the gene pool. Common sense dictates our starting points. If we were concerned with the development of a dairy breed, the Jersey, Holstein, and Sahiwal are obvious choices; we would not start with the Hereford or American Brahman.

The Best Ratio of Indicus/Taurus Blood

In the Indian subcontinent an enormous amount of effort has been directed at the production of a range of genotypes with a different proportion of 'exotic' blood (Nagarcenkar 1982). There still seems some doubt as to whether the optimum is ½, ⅝, or somewhere in between. Again, from the point of view of breed development, this seems a futile exercise. Our main concern is to maximize genetic recombination between adaptation and production (despite their physiological inter-relationships, we would like to take advantage of any independent genetic variability), and we would also like to maximize the frequency of any desirable genes. From these points of view, 50% of each species is the obvious choice.

The Role of Crossbreeding

I have so far been quite critical of much of the crossbreeding effort in the tropics, but I do not wish to dismiss entirely the value of crossbreeding. I am very mindful of the sociological and political importance of delivering improved livestock into the hands of smallholders as quickly as possible. There is a very considerable heterotic component in the performance of *Bos indicus* x *Bos taurus* crossbreds, and, provided that their distribution is accompanied by appropriate nutritional management, these hybrids can play an important role in the rapid increase in productivity. However, the exploitation of species crosses is a short-term strategy and, in some tropical countries, is already nearing the end of its usefulness.

Crossbreeding can be a useful tool in the improvement of traits that have a low heritability, such as reproductive performance. If a workable rotational crossbreeding scheme were developed in a particular tropical environment, it could not be based on markedly different breeds such as purebred representatives of *Bos indicus* and *Bos taurus* . Rather, we would require a number of tropically adapted breeds, each with roughly comparable performance, and each preferably derived from different genetic backgrounds.

Another application for crossbreeding is to combine a variety of breeds that have different mature body size and maternal characteristics, aiming to produce offspring with rapid growth rates from parents of moderate mature body size. A common example is the use of a three-way cross involving, perhaps, a beef breed, a dairy breed, and a large terminal sire breed. Once again it would be necessary to develop a range of tropically adapted breeds in order to exploit such a crossbreeding system.

In general, however, I believe that an over-concern with crossbred performance leads to stagnation in genetic progress. The utilization of heterosis must be a by-product of selection programs to improve performance, rather than an end in itself.

Estimation and Prediction in Heterogeneous Populations

With the advent of computer algorithms for the application of mixed model equations to breeding programs, including maximum likelihood methods such as REML (Patterson and Thompson 1974) for the estimation of genetic parameters, and BLUP (Henderson *et al.* 1959; Henderson 1977) for the prediction of genetic values, we now have powerful tools for the implementation of animal breeding and the monitoring of genetic progress. This is particularly true if complete pedigree information is maintained.

The theoretical and practical development of these statistical techniques has so far been centred on improvement programs in well established purebred temperate populations. Their application to breeding programs in the tropics may require careful consideration of appropriate statistical models. In addition, the application of REML and BLUP theory to heterogeneous populations still requires theoretical development. We could, for example, ascribe to each animal a vector that identifies its breed composition, together with an appropriate set of heterosis parameters. Suppose, for example, we were working with a population derived from four breeds, e.g. Brahman, Africander, Shorthorn, and Hereford. In this case we would need to estimate four fixed effects representing the mean genetic value for each breed. The adjustment for heterosis is much more difficult. One possibility would be to calculate an adjustment for each breed combination. A better alternative, I believe, is to estimate the expected increase in heterozygosity from the breed composition of the parents. An approach of this kind is necessary to remove biases in estimating the breeding values of animals and to predict the performance of an animal based upon additive and non-additive genetic contributions.

The Cytogenetics of *Bos taurus* x *Bos indicus* Crosses

European and Zebu breeds of cattle have been sexually isolated for a long time, and therefore have diverged genetically. Sexual isolation leads to speciation and in most mammals this is reflected in chromosomal rearrangements and meiotic abnormalities in the germ cells leading to sterility in the hybrids. This phenomenon is apparent to crosses between Banteng and European cattle and, to a lesser degree, between the swamp and river buffaloes. While the very considerable heterosis between *taurus* and *indicus* is due to the genetic differences between the two species, it is possible that these differences may also contribute to the lowered fertility of Brahman by European crosses (Rendel 1981). There is one apparent difference between the karyotypes of the two species under light microscopy, and this is a difference in the size of the Y chromosome (Kieffer and Cartwright 1968). Since the Y carries male-determining genes, any rearrangement involving the Y may have an effect on fertility. Reciprocal crosses have been established at Rockhampton in order to test the effect of this Y-chromosome difference on fertility. Work in the Division of Animal Production has shown that meiotic abnormalities, in the form of tetraploid spermatocytes, do exist in Brahman but not in Africander crossbreds.

Recently, electron microscope studies of the synaptenemal complex in Brahman and Sahiwal crosses has revealed the existence of a reciprocal translocation (Wagner, unpublished), and this will have the effect of producing unbalanced gametes. The presence of this rearrangement in both Zebu breeds indicates that this is a species difference. At present, the contribution of either of these phenomena to infertility in Brahman crosses is not clear, but it does reveal another complication in the development of new breeds from crosses between these species.

Dairy and Beef, or Dairy-Beef?

In Australia and North America, beef and dairy are largely separate industries; in Europe a considerable fraction of the beef consumed comes from the dairy industry. The trend in SE Asia, Africa, and Central America is not yet clear, but I suspect that dairy industries will contribute substantially to beef production in most of these regions. The arguments often put to me in favour of using Friesians rather than Jerseys are frequently based on the perceived superiority of the former as a meat animal. Clearly the smaller breeds are quite edible, especially if slaughtered at an appropriate finish. To my knowledge there has been no analysis of the performance of beef and dairy breeds in the tropics where the total value of product (calves, meat, milk) versus costs has been determined on a per hectare basis.

Breeding Objectives and Selection Criteria

There are several kinds of objectives that influence animal breeding policy. National objectives for an industry may be determined by political or sociological considerations. The objectives of a producer are almost overwhelmingly dominated by immediate economic factors. Breeding objectives, however, cannot be formulated solely on the economics of the current industry. The economic importance of a particular trait must be weighted by its heritability, and its genetic correlation with other factors. It may be necessary to forecast future research findings. For example, if we can confidently predict the development of immunization for certain diseases or parasites, the importance of genetic resistance as an objective may be diminished. Very often the formulation of specific objectives, such as the relationship between body size and production efficiency in a particular environment, requires further research. Breed evaluation can play an important role in the definition of objectives if the purpose of the evaluation is not simply to compare strains, but to better understand the components of production efficiency in a range of environments.

We can easily define breeding objectives in general terms: they are adaptation and production. We know from the work of Frisch and Vercoe (1982) that the two broad objectives are physiologically antagonistic. We lack suitable selection criteria for a number of adaptive traits. There is little information on the genetic and phenotypic correlations necessary to develop optimal breeding programs. A possible strategy is to select only for production in the target environment, and to allow natural selection to look after adaptation. This has its disadvantages (Franklin 1983). The alternative is to develop a sufficient understanding of the genetic and physiological relationships between adaptation and production in order to select for each simultaneously.

The following are some brief comments on some of the objectives and selection criteria that might be used in a tropical cattle breeding program.

Body Size

When feed supply is of high quality and always plentiful there is little doubt that smaller unit costs associated with maintaining fewer animals favours the large beast. When feed quality is poor, or worse, seasonal, it is far from clear whether the higher maintenance requirement of large animals is a disadvantage. In the only attempt, that I am aware of, to model tropical beef production at the herd level, Cartwright (1982) describes some work by Ordonez, who concluded that an intermediate body size produced the greatest returns. Also, because of the ratio of surface area to body volume decreases with size, large animals may be at a disadvantage with respect to heat dissipation. Counter-balancing this the requirement for large animals for draught in some countries. The question of optimum body size for cattle in the tropics seems far from resolved.

Heat Tolerance

Our methods for measuring and selecting for heat tolerance are inadequate. We know that it is important; heat stress reduces fertility and depresses appetite. The only comment that I wish to make is that it may not be enough to utilize the existing heat tolerance of the adapted breeds, for as we select for higher production, we expect increased heat loads, and hence, a requirement for greater heat tolerance.

Resistance to Disease and Parasites

Most of the health problems of temperate cattle in the tropics are generalized rather than specific, and are a result of poor adaptation. Resistance to ticks is important under extensive conditions, and their control by chemical means has increasing problems due to acaracide resistance and increased consumer sensitivity to residues in meat and milk. Resistance to artificial infestation provides a satisfactory selection criterion with a reasonably higher heritability, and there is no evidence of a strong negative correlation with production. The promise of immunization or of the direct measurement of antigenic response will either eliminate the need for selection or provide a cheaper method for selecting animals.

Temperament

Poor temperament can increase handling costs and reduce the value of meat through bruising. Most behavioural traits have a high heritability and respond well to selection (Fuller 1969), provided, of course, that a suitable criterion for selection can be found. Culling for improved temperament in CSIRO's tropical dairy program has been very successful. In addition, the removal of animals that are difficult to handle can make the rest of the herd easier to manage.

Conclusions

The preceding discussion has concentrated on the selection of tropical cattle breeds from an initial population derived from crossing representatives of *Bos taurus* and *Bos indicus* . I do not wish to leave the impression that this is the only starting point for a selection program. The selection for increased performance within already adapted breeds should be part of the overall strategy for cattle production in the humid tropics. Conversely, the selection for adaptation in *Bos taurus* breeds must also be considered, for there are numerous *B. taurus* populations in Africa and Central America that have acquired tolerance to heat, parasites, and disease. As I suggested at the beginning, the choice of a crossbred is a compromise. Just as the Zebu breeds are adapted to tropical environments, and European cattle to temperate climates and management systems, the crossbred is, in a strict sense, adapted to neither. In order to exploit their potential fully, either a management system needs to be created to match their capabilities or they will have to be modified in some way by selection.

Selection programs should be small, well designed and as simple as possible. Perhaps this is stating the obvious. At present we lack the necessary information (genetic and phenotypic parameters, economic weights) to construct selection indices, and often, in the tropics, the technological infrastructure to carry out complicated crossing programs and multi-trait selection. Most breeding programs fail to realize their maximum response because of violation of the rules. Strict adherence to the design is hard enough to ensure even in simple breeding programs. I have argued elsewhere (Franklin 1982) that a number of small programs may be better than a single large one. It would be an advantage to simultaneously develop a number of improved breeds, both beef and dairy, in order to exploit heterosis and to allow the better use of a range of environments and management systems.

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Historical Perspectives and Implications for Breeding Research in the Philippine Cattle Industry

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THE Philippines, comprising approximately 7100 islands and islets, stretches 1851 km from north to south and 1107 km from east to west. The country lies between 21° 25′ N and 4° 23′ N latitude and between 116° E and 127° E longitude. Its approximate land area is 300 000 km². Eleven islands make up about 96% of the total land area; there are only 357 islands with areas of 2.5 km² or more (Philippine Yearbook 1975).

There are only a few types/strains of Philippine native cattle that are identifiable, such as those from the Ilocos provinces (northern-western Luzon); the Batangas type in the southern Tagalog provinces; the Masbate/Iloilo types of the Western Visayas group, etc. Undoubtedly government and private introductions of imported animals have had some effect on the Philippine native cattle.

The second World War very seriously decimated the cattle population of the Philippines. It even wiped out what could have been a very good beginning in the large-scale propagation of the so-called 'Philamin' breed produced by the College of Agriculture from triple crosses of Philippine cattle, the American breed (Hereford), and the Indian breed (Nellore). The Philamin was the work of Gonzalez and associates (1932) for many years. The campus of the University of the Philippines at Los Baños was one of the concentration camps for prisoners of war, and this resulted in the complete destruction of the Philamin, the Berkjala (swine), and the Los Baños Cantonese (poultry), which were improved breeds/strains of animals for farmer testing and dissemination.

As shown in Table 1, the annual increase in cattle population has declined in the last 12 years and is very much smaller (0.5%) than the increase in human population (2.8%). The much smaller population base of the former together with poor nutrition and management may have contributed to the small growth increments. Because of the demand for more red meat by the middle and upper middle classes and the greater affluence of society, the extraction rate for cattle increased. This was influenced further by the ban on the slaughter of carabaos before 11 years of age for breeding females, or 7 years for males. In the 60s and early 70s, between 60-70% of large animals slaughtered in Metro Manila abattoirs were carabaos but with the enforcement of the ban this figure drastically changed; the increased rate of extraction of cattle drastically reduced their rate of population increase (Table 1).

Table 1. Human and cattle population of the Philippines for the years 1948-1982.

Year	Human Population		Cattle Population		Human to Cattle Ratio
	Number (million)	Increase %	Number (million)	Increase %	
1948	19.2		0.7		27.4 : 1
1960	27.1	41.1 (3.4)*	1.1	57.1 (4.8)	24.6 : 1
1970	36.7	33.2 (3.3)	1.7	54.5 (5.5)	21.6 : 1
1982	49.0	33.5 (2.8)	1.8	5.9 (0.5)	27.2 : 1

*Figures in parenthesis are annual rates of increase in per cent.

Source of data: Concepcion and Smith 1977; 1980 Philippine Statistical Yearbook; 1982 National Census and Statistics Office; 1983 Bureau of Agricultural Economics Report on Livestock and Poultry Population.

At present the Philippines imports quite a substantial quantity of frozen beef, mainly from Australia and Argentina. In 1981 beef importation was 5661 tonnes (t) costing $13.5 million and in 1982 the corresponding figures were 7451 t and $17.1 million (PCARRD 1983). Our milk importation in 1982, representing 99% of what we consumed, amounted to about $165 million from Australia, New Zealand, United States, and European countries.

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Historical Perspectives and Implications of Cattle Importations

Importations from 1900-1940

In 1903, two Jersey bulls and five cows from the United States, and one Jersey bull and one Shorthorn bull from Australia were introduced (Tuason 1933). This was followed by the importation by the Bureau of Agriculture of 64 Jersey cows and one bull from the Texas fever belt around Mississippi, USA, in 1904. A few Holsteins were included in this shipment. Only seven of this importation survived after rinderpest hit the herd. Subsequent efforts were made with importations from the USA and Australia. But in 1910 the Bureau of Agriculture gave up the project and reported that the 'American and Australian cattle kept in this farm had not done well in spite of a liberal ration of concentrate feeds. The amount of milk given by the cows was about one half of what they would give in the United States under similar circumstances'. It further recommended that no more attempts be made to grow this kind of cattle. The second attempt to build a dairy farm was made in 1928 with 50 head of cows from Seattle, composed mainly of Holsteins and a few Jerseys and Guernseys. Then subsequent importations were made in 1930-1935 to bolster dairy farms under private management (Sarao 1947).

The beef and dual purpose breeds of Zebu cattle have been introduced in the Philippines. The beef breeds are Nellore, Hariana, and Bhagnari while the dual purpose dairy breeds were the Sahiwal, Red Sindhi, and Tharparkar. The first importation of Nellore was made in 1905. Other importations were made in 1909 followed by six other shipments up to 1921.

Galloway, Angus, Devon, Hereford, and Sussex bulls were also introduced.

Importations from 1946-1970

Nellore, Hariana, Bhagnari, Sahiwal, Red Sindhi, and Tharparkar were imported from India and Pakistan (Villegas 1958). Brahman, Chiricano, and Santa Gertrudis breeds were also introduced during this period. As a part of the rehabilitation aid from the USA government, a few Brown Swiss and Holsteins were also brought into the Philippines. Red Danes, Illawarra, Holsteins, and Jerseys were purchased by private farms. Bali cattle were also imported (BAI 1983).

Importations from 1971-1983

The following breeds were imported by various entities: Brahman, Santa Gertrudis, Indu-Brazil, Droughtmaster, Beefmaster, Belmont Red, Santa Gertrudis crosses, Brahman crosses, Holstein, and Charolais (BAI 1983).

Implications of These Importations

In summarizing the country of origin for these cattle importations, Australia ranks first as the main supplier, with the USA a far second. In terms of number, Santa Gertrudis ranks first with 15 005 head imported from 1968 to 1983, followed by the Brahman breed with 13 576. For dairy cattle, Holstein dominates with 374 imported since 1977. In the choice of breeds to import, whether it be for beef production or milk production, preference of the importer or individual is of paramount importance. It is influenced by experiences with the existing breed. Filipino dairy cattle entrepreneurs prefer Holstein.

The role of crossbreds should not be underestimated. They fill a special place in the cattle enterprise with the advantages of resistance to environmental conditions with possibly better performance and also lower prices without sacrificing production performance.

Throughout the country the Brahman breed is predominant suggesting that this breed is here to stay and will undoubtedly play an important role in building up our beef cattle production endeavours (de Guzman Jr., pers. comm.). This reflects the productivity of the animal under our tropical, hot humid environment. On the other hand, the Santa Gertrudis is finding some difficulty in competing with the Brahman under field conditions. Resistance to diseases and pests or parasites is a big factor.

The listing of the different breeds imported after the second World War shows that a number of adventurous, enterprising Filipino entrepreneurs dared to risk venture capital. It will be very bad if such ventures are limited in the range of choice by government prescription, but certainly well-considered decisions have to be based on the best information to minimize risks of investments. A poor country investing a sizeable sum on importing 23 breeds and their crosses is simply too much. Justifiably, the question is raised: What do we really want? There is plenty of room to narrow down drastically the field of choice after all these experiences. On the positive side, these experiences should provide substantial evidence for breed evaluation in the tropics.

Research Conducted

In 1960, Castillo *et al.* reported the 10 year performance in milk production of dairy cows at the University farm. The Holsteins average 1985 kg; Holstein-Red Sindhi crosses 1543 kg; Brown Swiss 1465 kg; and Red Sindhi 548 kg in 300 days of lactation. The Australian Holsteins imported by farmers in 1977 averaged 2785 kg in 335 days in the first lactation of 99 cows at semi-commercial dairy farms situated at an altitude of about 335 m (Castillo *et al.* 1979). More recently Devcota *et al.* (1982) stated that the production of these cows in 305 days were 1925; 2687; 2756; and 3004 kg in the first to the fourth lactations. Furthermore, the farm-born cows produced 2200 and 2266 kg in 305 days in their first and second lactations. The calving intervals of the original imported stock were 470, 426, and 382 days after the first, second, and third calvings. Natural service may have improved the conception rate because bulls were right on the farm while a timely artificial insemination service was not always available. Furthermore, good nutrition and experience in management might have contributed to this improvement in performance.

Action-research on artificial insemination activity is shown by the establishment of 116 artificial breeding centres and sub-centres, in the country. Bonifacio (1983) reported that the National Artificial Breeding Centre of the Bureau of Animal Industry inseminated 8866 cattle for small-holder farms and 6751 in commercial farms with either refrigerated or frozen semen in 1981. It appears that we have to intensify our efforts for more successful insemination services supplemented with records of calves produced, including their location and performance. There is a need for more field research on efficient and effective systems of improving our breeding stocks by artificial insemination and/or natural breeding.

Possible Areas for Collaborative, Integrative Research

1. The identification, conservation, and management of indigenous Philippine cattle and carabaos:

(1) Identification and evaluation of Philippine indigenous cattle and carabaos.

(2) Cytology and blood markers of Philippine indigenous cattle and carabaos.

(3) Karyotyping Philippine carabaos and crosses.

(4) Conservation and management of Philippine indigenous cattle.

2. Evaluation of existing imported breeds of cattle for beef, milk or draught purposes. Studies on improvements/machines for efficient use of animal power.

3. Improving artificial insemination delivery systems for more efficient and effective services and quantifiable responses in terms of increased calf crop. Research to include reproductive physiology aspects of both cattle and carabaos. An important aspect of this area of research is to include the impact of the socio-economic aspects of artificial insemination on the livestock industry and the farmers.

4. Pasture and forage development programs including the production and multiplication of suitable forages and legume species under the various climatic conditions of the country, and grazing management. Production of legume species that are suitable for leaf meal preparations with no (or minimal) inhibitors nor toxic factors for growth and reproduction in poultry and swine.

5. Studies on animal nutrition to be coupled with work on reproductive performance.

(1) High urea-molasses-mineral blocks as part of feeding systems for cattle and carabao production. Emphasis to be on the action-research aspects for small-holder farmers.

(2) Ensiled enriched rice straw and other fibrous agricultural residues as feed for cattle and carabaos owned by small-holder farmers: An action-research project.

(3) Studies on the rumen of Philippine cattle and carabao under different management and feeding practices.

(4) Determination of the mineral status of ruminants in the Philippines.

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Beef Breeds for the Humid Tropics: A Review of Papua New Guinea Experiences

J. Holmes*

THE technical difficulties of beef cattle production in the humid tropics (as opposed to the social and economic constraints) occur in four main categories:

1. Disease: A wide range of viral, bacterial, protozoal, and metazoal diseases occur.
2. Nutrition: Tropical pastures, especially unfertilized native pastures, are often characterized by a low content of nitrogen, available energy, and minerals, and consequently poor intakes.
3. Environment-breed problems: Inappropriate breeds are unable to survive the diseases, endure the climate, consume enough food and produce enough of the desirable end product.
4. Management: Technical knowledge may be unavailable, or lack of managerial ability or resources may preclude implementation of the best technical information.

The difficulties are real and great; but they are not exclusive to the humid tropics. Much has been written about these difficulties (e.g. Miranda 1975) and the impression is easy to obtain that cattle production in the humid tropics, especially in less developed countries, cannot reach the levels of performance in temperate zones.

In this presentation I will discuss the results of six years of investigations in Papua New Guinea, (P.N.G.), and demonstrate that:

1. In some instances, extremely good rates of beef production can be achieved when these four constraints are corrected, while poor performance can be explained in these terms.
2. The appropriate breed type is essential; it may not be obtainable by simply combining breeds but requires selection.
3. The appropriate breed type may be already present, under-fed, under-managed, and unassessed.

In particular, I will discuss the performance of one type of cattle indigenous to Southeast Asia.

Two major breeding programs were set up in the 1960s to produce crossbred cattle; in the dry lowlands of Papua, Anderson (1961) established a Brahman x Angus and polled Shorthorn program, and in the Markham Valley, a program using Africanders over Shorthorn and Angus cattle. By 1973 no attempt was being made to maintain the Africander lines and the transfer of bulls among research stations had blurred breed differences. The cattle on the Government stations were either Brahman (grades and purebred), Brahman (and Africander) crossbreds, usually ½ to ¾ Brahman and Africander, ½ to ¼ British breeds, or Droughtmasters, imported in the 1960s and used widely but not systematically. Some data are available in Dept. of Agriculture Stock and Fisheries Annual Reports and station records, but a complete analysis of these programs from 1960 onwards is not available.

The results presented in this paper are derived from a number of trials with these and other cattle that were performed in P.N.G. between 1973 and 1979. Although the trials had diverse purposes, being often not designed as genetic studies, the data have now been re-analysed to extract information about the performance of different strains and breeds of cattle. These trials were not a coherent series and aspects of design such as duration, group size, etc. are not consistent. For the purposes of this workshop, extrapolations have been performed for indicative purposes, although the precision may be low.

The humid tropics is not one environment or group of environments with enough in common that similar pastures, livestock and management can be used. In P.N.G. alone, grazing land is utilized from sea level to 3000 metres altitude; soils range from acidic, waterlogged, phosphate-deficient clays to basic, free-draining, recent alluviums; gradients vary from flat to extremely steep and rainfall ranges from 1200 to over 4000 mm per year, with one or two wet seasons, or a continuous wet season. Livestock managers in the temperate zones consider it obvious that a range of species and of breeds within species is essential to utilize the range of environments found there. But in some tropical countries, in areas of as

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variable a range of environments, the need for diversity in livestock, pastures, and management systems seems to be not as clearly appreciated.

Livestock Diseases

The livestock disease situation in P.N.G. would be the envy of most countries. Being east of 'Wallace's line', the islands have no indigenous ruminants, pigs, or horses. As a result, livestock imported from Australia (cattle, sheep, goats, horses) or South East Asia (cattle, sheep, rusa deer, pigs, water buffalo) have not contracted diseases from local animals and these do not act as reservoirs of diseases of domestic livestock. The importers, whether recent or prehistoric, have managed to exclude most of the major viral and bacterial plagues (Egerton and Rothwell 1964) while brucellosis and bovine tuberculosis are thought to have been eliminated during the last twenty years. Screw worm fly (*Chrysomia bezziana*), buffalo fly, cattle tick (*Boophilus microplus*) (in limited areas), and internal parasites (worms and fluke) are found. At the Beef Cattle Research Centre, Erap, Morobe Province, we did not need to drench regularly, vaccinate for any disease, dip or spray cattle (except recently for buffalo fly), nor did the majority of cattlemen. In many areas of the Highlands drenching was necessary for control of fluke and for worms in weaner calves.

Nutrition

The nutritional situation in the Lowlands at Erap is exemplified in Figure 1, which combines the results of several grazing trials, each extending over a number of years and utilizing some hundreds of cattle in total. Individual animals usually spent 12 months in a trial.

The results show that unsupplemented *Imperata cylindrica* (lalang, alang-alang, cogon, kunai) did not support good growth rates at any stocking rates (Holmes, Lemerle, and Schottler 1980). Under Erap conditions, the sowing of Stylo (*Stylosanthes guianensis*) into *Imperata* did not increase growth rates except at the lower stocking rates, since Stylo was preferentially grazed and did not persist well on these basic soils (on less basic soils where *Stylosanthes* flourished, *Imperata*-Stylo pastures supported high stocking rates and rapid growth). At Erap, better performance is achieved with *Dichanthium annulatum*, a dense turf-forming perennial grass, without legumes or salt supplementation

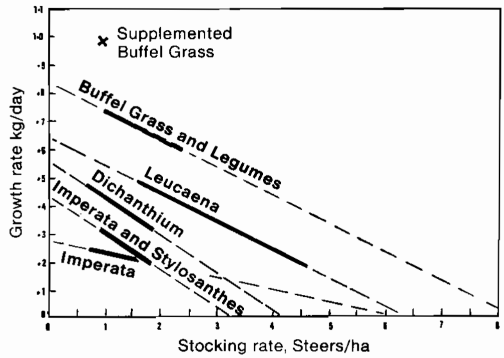

Figure 1. The relation between stocking rate and growth rate of Brahman crossbred cattle on a variety of pastures at Erap, Markham Valley, P.N.G. Range of actual data indicated by solid lines.

(Holmes 1981a). *Leucaena leucocephala* gave an even better performance despite the consistent occurrence of minor toxic symptoms (Holmes 1976, 1979, 1981c). However, best performance was achieved with an improved grass (Buffel grass, *Cenchrus ciliaris*) with legumes (*Calopogonium mucunoides*) and Siratro, *Macroptilium atropurpureum* and salt supplement; growth rates were up to 0.73 kg/day, year round, at one steer/ha, and 0.65 kg/day at 2/ha (Holmes 1981c; Lemerle and Holmes, in press and unpublished data). If these cattle were supplemented with 'mill run' at 3.3 kg/day, a growth rate of 1kg/day was achieved over a 4 months fattening period (Gwaiseuk and Holmes, in press).

The regressions of growth rate (y, kg/day) on stocking rates (x, number of steers of about 300 kg/ha) and the ranges of stocking rates employed in the trials were:

Imperata: y = 0.28 - 0.14x. Range 0.78 to 1.6/ha
Imperata: + Stylo: y = 0.42 - 0.30x. Range 0.94 to 1.8/ha
Dichanthium: y = 0.55 - 0.13x. Range 0.75 to 1.83/ha
Leucaena: y = 0.63 - 0.10x. Range 1.6 to 4.6/ha
Buffel grass + legume: y = 0.83 - 0.02x. Range 1.0 to 2.4/ha

The cattle used were Brahman crossbreds (½ to ¾ Brahman and Africander, ½ to ¼ Shorthorn, Angus) bred at Erap in a herd selected for performance for 15-20 years. The major limiting factor under these conditions is quite obviously nutritional, i.e. pasture quality, and salt supplements, while the breed type is satisfactory, diseases and management present few problems.

It appears that this type of cattle performs well in the Lowlands climate on improved pasture. The next trials compare the performance of different genotypes under various P.N.G. conditions, using the Erap herd as a reference point.

Difference Between Breeds and Strains of Cattle

1. Changes during the 1960s and 1970s: The foundation herd at Erap was Shorthorn. In 1962, Glasgow (1966) recorded a growth rate of steers, over a period of 12 months, of 0.29 kg/day. These animals were grazing native pastures and receiving salt supplementation. In 1976, steers from this herd, now about ⅝ Brahman Africander, grazing native pastures, without salt, grew at 0.51 kg/day (Table 1). In 1966 (DASF 1969) calves at Erap grew at 0.34 kg/day (¼ Africander ¾ Shorthorn), 0.48 (½ Africander ½ Shorthorn), with 3/8 Africander, ¾ Africander and Droughtmaster intermediate. By 1976, the pre-weaning growth rate of crossbred calves had been increased to 0.72 kg/day (Table 2). These changes in performance were presumably achieved by selection in highly fertile cattle where selction pressures were able to be kept high. A rapid turnover of staff on all Government stations and a low emphasis on analysis and publication has resulted in little information about the selection programs being available. The original records are available, but to a considerable extent unanalysed.

Reproductive performance of Shorthorns was 19.6% calving in 1960-61, 22% in 1961-62, 39% in 1962-63 (DASF 1965) rising to 74% and 85% for ½ Africander and ½ Brahman respectively, from 1967-1969. However ¼ and ¾ Africanders had only 59% and 61% calving. In 1976 the average calving rate across all crossbreds was 88%. Reproductive performance seems to have increased with the F_1 then declined in Africander F_2, and increased steadily subsequently as did the growth rates of calves. Data on all performance parameters are confounded by a steady improvement in pastures at Erap. Nevertheless, this somewhat disjointed program, combining Shorthorn, Angus, some Red Poll, with Brahman, Africander and Droughtmaster, had produced well adapted cattle by 1973.

2. At Erap, on Buffel grass pastures, Lemerle and Holmes (in press) compared purebred Brahman and Droughtmaster-type (½ Brahman) crossbreds, with and without salt supplementations. Table 3 gives the growth rates of yearling heifers over a period of 4 months at the end of the dry season. Droughtmaster-

Table 1. Growth rate (g/day) of yearling cattle from four research stations grazed for 12 months at eight sites in P.N.G. without mineral supplementation (S.E.M. 35 g).

Origin of cattle	Erap: improved pasture	Singaua: improved pasture	Erap: native pasture	Lanakalana: native pasture	Baiyer River improved	Muli: native pasture	Urimo: native pasture	Aroma: native pasture
Erap	750	595	512	393	255	125	—	88
Baiyer River	678	546	426	—	280	110	140	103
Urimo	538	—	—	—	347	234	144	—
Herd IV	—	—	328	98	210	—	—	63

Table 2. Performance of Javanese Zebu and Brahman crossbred cattle at two sites (calving interval in days, growth kg/day, weaner production in kg of 200-day-old weaner per year per cow mated).

Site	Javanese Zebu			Brahman crossbred		
	Calving interval days	Growth kg/day	Weaner production kg/cow/year	Calving interval days	Growth kg/day	Weaner production kg/cow/year
Erap	358	0.475	118	415	0.72	155
Urimo	468	0.50	94	830	0.35	45

Table 3. Growth response to sodium in heifers of two tropical breeds grazing Buffel grass pastures at Erap, in the Markham valley of P.N.G.

Salt intake	Purebred Brahman kg/day	Droughtmaster type (½ Brahman) kg/day
Adequate salt	0.66	0.78
No salt provided	0.57	0.61

type crossbreds grew much faster than the smaller purebred Brahmans, when salt was not limiting. When salt was not supplied and sodium deficiency occurred, the depression of growth of Brahmans was only half of that of the crossbreds. Thus, even under these relatively benign conditions, the toughness of the Brahman was expressed in the face of a minor nutrient deficiency and the potentially more productive cattle were reduced to the level of the Brahman.

3. A large scale genotype-environment study was carried out using 220 steers and heifers from four Government stations grazed at eight sites for a year (Holmes 1981d). The cattle were ½ to ¾ Brahman crossbred type, originating from Australian stock imported in the 1950s and 1960s. The original herds would have been rather similar genetically since a considerable amount of exchange of bulls had occurred. The Erap and Baiyer River herds had undergone selection for growth rate, calving rate, temperament and conformation for over 15 years, and the Urimo herd was selected similarly since 1967. The fourth herd, Herd IV, had existed in Central Province for 15 years but had not been subject to such careful selection as the other herds. Initial ages and weights were: Erap steers, 7-10 months 187 $\pm$ 26 kg (S.E.M.); Baiyer River steers, 7-9 months, 154 $\pm$ 9 kg; Urimo heifers, 7-9 months, 104 $\pm$ 11 kg; and Herd IV heifers, 8-12 months, 144 $\pm$ 35 kg.

The sites were:

(1) and (2) Erap: Altitude 100 m, rainfall 1250 mm, two wet seasons. Basic gravelly soil. Hot; humid or dry depending on seasons. Erap site (1) = native pasture (*Imperata cylindrica* (Kunai) oversown with some *Stylosanthes*) and Erap site (2) = improved pasture (*Cenchrus ciliaris* (Buffel grass) and *Macroptilium atropurpureum* (Siratro)).

(3) Baiyer River: Altitude 800 m, rainfall 2000 mm, one wet season, warm climate, humid. Drained swampland. Pastures *Setaria* sp and *Pennisetum purpureum* (Elephant grass).

(4) Urimo: Altitude 200 m, rainfall 1800 mm, no marked dry season, hot, very humid, acidic clay soil. Natural grassland. Pastures: *Imperata cylindrica, Themeda australis, Lochaemum barbatum,* and sedges.

(5) Lanakalana: Altitude 20 m, rainfall 1200 mm, hot, marked dry season. Natural grassland and light scrub. Pastures: *Imperata cylindrica, Themeda australis, Saccharum* spp, a small amount of *Stylosanthes guianensis.*

(6) Singaua, Morobe Province: Altitude 5 m, hot, wet, rainfall 4000 mm, no dry season, gravelly waterlogged soils; cleared primary rain forest planted to *Leucaena leucocephala, Brachiaria mutica, B. decumbens.*

(7) Arona: Altitude 1650 m, rainfall 1850 mm, cool, humid, highlands climate, natural grassland. Pastures: *Imperata cylindrica, Themeda australis,* a small amount of *Stylosanthes guianensis.*

(8) Muli: Altitude 2000 m, no marked dry season, rainfall 4 000 mm, cool, overcast climate, peaty soils on swampy hills. Pastures: *Saccharum* sp, *Paspalum* sp, *Setaria.*

Stocking rates ranged from one beast/ha at site (2) Erap, to one beast/5 ha at Urimo. Phosphate deficiency occurs at Urimo (Holmes 1981b) and Muli, and sodium deficiency occurs at Erap (Lemerle and Holmes, in press) and throughout the Highlands (Leche 1977a,b). Growth rates (Table 1) showed that the eight sites ranked in the same order for each strain of cattle, with few exceptions. While Erap steers were best under good conditions, Urimo heifers were as good or better under harsh conditions. Baiyer River cattle appeared intermediate to these strains due to performing worse than Erap steers in the first 6 months in the lowlands, while Herd IV cattle were worst in growth and temperament.

The breeding programs at Erap and Baiyer River have produced quiet cattle capable of rapid growth if conditions permit. Urimo cattle are very tough cattle, living in an environment where cow mortality in 1973 was 16.5% and the annual calving rate from 1968 to 1974 was 41%. The breeding program of Herd IV was disrupted by changes of management and transfer of the herd from another site near Port Moresby. Under benign conditions, natural selection was also low, and the result is seen in these cattle, which are neither hardy, fast growing nor easy to handle. Nevertheless, they are ⅝ Brahman, bred for 3-4 generations in the humid tropics and could have been expected to be adapted to the environment.

Selection under local conditions is seen to be all important: making a genetic mix does not guarantee an appropriate genotype.

It should be noted that the poor performance of all cattle in the Highlands and at Urimo could be greatly improved by mineral supplementation. At Urimo, phosphate supplementation increased growth rate by 0.21 kg/day (Holmes 1981b). At Arona, salt supplementation increased growth by 0.35 kg/day, while at Muli and Baiyer River, animals receiving salt supplementation grew at 0.49 kg/day.

4. The toughest type of cattle in P.N.G., which are known locally as 'Javanese Zebu', are supposedly derived from cattle of Java, Sumatra, and Thailand that were imported last century (Purdy 1972). They look somewhat like Java village cattle, a little like Kedah-Kelantan cattle, and these cattle are probably a mixture of several types. They are used mainly on coconut plantations where their function as grass removers requires constant overstocking, with minimal management inputs supplied; thus they are being continually selected for toughness. They are small, fine boned, and well muscled when well fed. Bulls weigh 500-600 kg, cows 300-400 kg. Coat colours include white, black, red, spotted, and pied, but the most common colour is fawn, with darker fore and hind quarters, and sometimes a black stripe down the spine. 'Banteng' markings have never been seen. Horns curve up and forward, ears are small, pointed and horizontal, the skin does not have loose folds, and the prepuce is not pendulous. Males have Brahman-type or thoraco-cervical humps. Temperament is alert and active, in the field, but rather excitable under close confinement or when young calves are present. The cows are good, defensive mothers, and calf survival is high.

Table 2 presents a comparison of pregnancy rates and the pre-weaning calf growth for Brahman crossbred and Javanese Zebu under 'good' (Erap) and 'poor' (Urimo) conditions. Javanese Zebu were extraordinarily fertile: some individuals in other trials had a series of four consecutive calving intervals averaging 320 days. This was strongly associated with 'condition' of the cows, and apparent vigour. Growth of calves was not particularly good under favourable conditions but not worse under poor conditions, whereas the Brahman-cross cattle reduced both calving rate and calf growth to half the performance achieved on good country (Holmes 1976). At Urimo, there was a direct relationship between calving percentage (40-100%) and Javanese Zebu appearance, in a herd of crossbred cattle classed by two observers.

On buffel grass pastures at Erap, the post-weaning growth rate of Javanese Zebu, up to slaughter at an acceptable degree of fatness, was only ¾ of that of Brahman crossbreds (Table 4). Despite this, Javanese Zebu had slightly higher dressing percentage and greater back-fat thickness (Holmes 1979).

Table 4. Growth rates and carcass data for Javanese Zebu and Brahman crossbreds grazed together on Buffel grass, at Erap. These data were from 11 months grazing, during a drought, hence the low growth rates.

	Growth rate kg/d	Carcass wt,kg	Dressing %	Back Fat mm
Brahman crossbred	0.40	212	59.2	3.8
Javanese Zebu	0.30	170	60.3	6.4

Gwaiseuk and Holmes (in press) compared these cattle on better quality pasture, and with various levels of supplementation with 'mill-run'. Again, under grazing conditions, Javanese Zebus grew at about ¾ the rate of Brahman crossbreds at the same age. But when grazed for 20 hours per day and penned and fed 'mill run' for 4 hours/day, growth rates of Javanese Zebus were almost 1 kg/day (Table 5).

Table 5. Growth of Javanese Zebu (JZ) and Brahman crossbred (BX) steers under different nutritional treatments, grazing (Buffel grass at 3 steers/ha) or grazing plus access to mill run pellets for four hr/d.

		Amount fed g/kg $BW^{.75}$	Growth kg/day	Carcass wt,kg	Dressing %	Backfat mm
Grazing	JZ	0	0.61	192	55.6	6
	BX	0	0.83	194	54.2	4
Grazing supplemented	JZ	43	0.97	215	57.4	9
	BX	51	1.07	215	54.9	8

The Javanese Zebu cattle had higher dressing percentages and thicker back fat than Brahman crossbred cattle of the same live weight. Javanese Zebu had heavily muscled, blocky carcasses, with less narrowing at the lumbar region than the Brahman crossbred. Occasional Javanese Zebus had yellow fat, at 1-2 years of age, of an intensity suggesting much greater age. Regressions of carcass weight (Y) on live weight (X) were calculated for all Javanese Zebu (21 steers between 200 and 380 kg) slaughtered at Erap, and for groups of light Brahman crossbred (16 steers) in the same weight range (200-380 kg) and for 17 fattening Brahman crossbreds (380-520 kg).

Javanese Zebu $Y = -23.9 + 0.648 X$ (S.E. of reg.coeff. = 0.030)

Light Brahman crossbreds $Y = -9.9 + 0.581 X$ (S.E. = 0.007)

Heavy Brahman crossbreds $Y = -32.8 + 0.654 X$ (S.E. = 0.025)

Carcass gain made up a greater proportion of live weight gain in Javanese Zebu than in Brahman crossbreds of the same weight, much more like the fattening Brahman crossbred. Regressions of backfat (Y, mm) on carcass weight (X) were:

Javanese Zebu: $Y = -8.14 + 0.0685 X$

Brahman Crossbreds $Y = -7.88 + 0.0609 X$

Table 6 shows the carcass weights and live weights needed to produce carcasses of varying degrees of fatness. Javanese Zebu cattle produce an acceptable carcass weighing 91% of a Brahman crossbred carcass of the same fatness, at about 87% of the live weight of such a Brahman crossbred at 2-2 ½ years old. By combining the birth weights, pre- and post-weaning growth rates and the data in Table 6, it is possible to calculate age at slaughter at Urimo and at Erap for varying degrees of finish, under various grazing conditions. At Erap, Brahman crossbreds always 'finished' first, between 2 and 7 months earlier, at growth rates from 0.4 kg/day (e.g. Table 4) on restricted pastures, to 0.8 kg/day on good grazing followed by 4 months supplementation (Table 5) due to about 15 kg superior birth weight, 51% higher pre-weaning calf growth, and faster post weaning growth. All animals would be slaughtered before 3 years old. At Urimo, however, Javanese Zebu would reach 3 mm of back fat 12 months before Brahman crossbreds, and 7 mm of back fat 16 months earlier at 30 months of age. In fact, it is questionable that Brahman crossbreds would attain 7 mm of back fat at the predicted age of 46 months, and weight of 424 kg.

Thus there is no question of the superiority of Javanese Zebu at Urimo, where they have double the calving rate and 'finish' earlier. At Erap, the superior growth of the Brahman cross is countered by the superior breeding of the Javanese, and more precise studies, especially stocking rate trials, are needed to determine which breed yields the greater amount of acceptable carcass per year per unit land area.

Table 6. Calculated slaughter weights and carcass weights for Javanese Zebu and Brahman crossbred steers at different degrees of 'finish' (back fat thickness) at the same ages, 2-3 years old.

Back fat	Finish	Brahman crossbred		Javanese Zebu	
(mm)		Carcass wt. (kg)	Live wt. (kg)	Carcass wt. (kg)	Live wt. (kg)
3	'Lean'	179	325	163	288
7	Adequate	244	424	221	372
10	'Fat'	294	500	265	435

In these trials it has been shown that:

1. Rapid growth rates can be achieved by cattle in the humid tropical lowlands, under grazing conditions;

2. There are considerable differences between breeds (Brahman and Droughtmaster type) and strains of crossbreds in their response to good and poor environments. Different strains appear to have been established in a few generations, by selection and vigorous culling.

3. A South-east Asian type of cattle found in P.N.G. is highly fertile under all conditions experienced, grows at 75% of the rate of Brahman crossbreds, and produces an acceptably fat carcass in a slightly longer time under good conditions. Under poor conditions they may be the only breed that can fatten at all.

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Productivity of Large Ruminants in Papua New Guinea and Solomon Islands

J.H. Schottler*

PAPUA New Guinea (P.N.G.) and Solomon Islands lie in the wet humid tropics between latitudes 4-12° S. Mean annual rainfall varies from 1000 mm to more than 4000 mm. Fire disclimax grassland predominates in the lower seasonal rainfall zones, with dense tropical rainforest in the higher rainfall areas.

The people are predominantly Melanesian, of whom the majority are subsistence farmers. The main exports are forest products, copra, palm oil, fish, and coffee.

History and Present Situation

There are no large ruminants indigenous to the region. The first cattle and water buffaloes (swamp type) were introduced around the 1880s by plantations and missions. The stock were mainly used as grass cutters in coconut plantations, often at high stocking rates. Meat and dairy products were welcome by-products of the system. Buffaloes were additionally used for draught purposes on a number of plantations.

The early importations into P.N.G. were the South-east Asian 'Javanese Zebu' cattle from Indonesia, water buffaloes from the Philippines and Indonesia, and temperate beef and dairy breeds from Australia. Most early importations to Solomon Islands were temperate beef breeds from Australia, although later importations from P.N.G., Vanuatu, and New Caledonia consisted of temperate and Zebu cattle. Freeman (1977) estimated that prior to World War II, the genetic composition of cattle in Solomon Islands was about 25% Zebu. The level of animal husbandry in both countries was very low, and productivity was correspondingly low.

During World War II, cattle numbers were drastically reduced in both countries from 16 000 to 1500 head in Solomon Islands, and from 30 000 to less than 5000 head in P.N.G.

Cattle numbers increased slowly after the war and a census in 1969 in Solomon Islands revealed 11 300 head, and approximately 30 000 in P.N.G. in 1960. In the late 1960s active efforts were made by both governments to increase the cattle population with the importation of cattle to nucleus ranches and plantations for later distribution to smallholders in P.N.G., and direct distribution of imported cattle to smallholders in Solomon Islands. The genetic composition of the cattle population was changing to around 50% Zebu, with the Brahman breed comprising the major Zebu component. In 1975 the cattle populations for Solomon Islands and P.N.G. were 23 000 and approximately 130 000 head respectively. There has been little or no increase in cattle numbers since that time due to a variety of reasons. Neither country is self-sufficient in beef, and full self-sufficiency in beef may not be a desirable goal.

Smallholder development was promoted by the departments of agriculture, but in 1977 the Solomon Islands Cattle Development Authority was created with responsibility for smallholder development and marketing of cattle. Pasture and ruminant research has been undertaken in both countries. The distribution of cattle in Solomon Islands by ownership and composition by herd size in 1982 is shown in Appendices 1 and 2. The estimated cattle population and distribution for P.N.G. in 1976 is shown in Appendix 3.

In Solomon Islands the majority of the cattle are grazed under coconuts or in clear felled rainforest areas, whereas in P.N.G. the majority are grazed on unimproved native grassland, although recently there seems to be a greater emphasis on pasture improvement. The ranch and plantation sectors manage their cattle on an extensive basis, and herd recording is not normally undertaken.

Although the objective of both governments has been the establishment of viable smallholder farms, the results have not reached expectations. Some of the reasons put forward include social and land tenure problems, Development Bank policies (which insist on a large proportion of sales for repayment), the long delay in obtaining returns, poor financial

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returns of cattle compared with alternatives, transport and marketing constraints, insufficient knowledge, inadequate managerial ability, and technical problems.

Today there is little or no increase in the smallholder sector. Smallholders own about 35-40% of the national herds. The management systems vary, but usually the cattle are confined to fixed areas. Herding is conducted on a small scale. A primary requisite for cattle on smallholder farms is docility.

Both countries are free of major exotic diseases. P.N.G. is thought to be free of brucellosis and tuberculosis. Solomon Islands is free of tuberculosis, but brucellosis is present in the government herd at Tenavatu. A test and slaughter policy is presently being undertaken to eradicate the disease.

Production Performance

Reproduction

An analysis of the breeding records of the government cattle herd at Erap, P.N.G. (Schottler, unpublished, 1972) indicated calving intervals of 457 and 424 days for Brahman/British and Africander/British cross breeds of cattle, respectively. The difference in length of calving interval between the two breeds just failed to reach statistical significance.

The results of two studies (Holmes *et al.* 1974; Schottler *et al.* 1977) of the productivities of Brahman cross, Javanese Zebu, and water buffalo at two sites in P.N.G. are summarized in Table 1. The studies were carried out at different times, and the herds of Brahman cross cattle numbering 50-60 head were different at each site.

At Erap in the Markham Valley, the climate is relatively dry with a mean annual rainfall of 1250 mm falling in two wet seasons. Soils are alkaline, free draining sandy loams, supporting pastures of buffel grass (*Cenchrus ciliaris*), kunai (*Imperata cylindrica*), kangaroo grass (*Themeda australis*), and some Siratro (*Macroptilium atropurpureum*). At Urimo on the Sepik Plains, rainfall is higher at 2000 mm. Soils are heavy meadow podzolic acid clays, deficient in phosphate and other minerals, and supporting a vegetation of sedges, *Ischaemum* sp, *Themeda*, and other grass species. Small areas of *Stylosanthes* sp have been established.

Table 1. Calving interval and cow productivity. Papua New Guinea

Location	Species/Breed	Calving interval (days)	Liveweight (kg) weaner/cow/yr
Erap:	Javanese Zebu	357	122
	Buffalo	414	123
	Brahman cross — Herd A	414	162
	Brahman cross — Herd B	415	153
Urimo:	Javanese Zebu	384	122
	Buffalo	424	108
	Brahman cross — Herd C	644	61
	Brahman cross — Herd D	540	82

The Javanese Zebu and buffaloes show shorter calving intervals than the Brahman cross at Urimo. During the period of the study the buffalo produced 50% more calves than the Brahman cross. Since the gestation period of the buffalo is a month longer than for the cattle, the interval from calving to conception was shorter. At Urimo, the buffalo were able to conceive during the period of live weight loss during lactation, whereas the Brahman cross did not conceive during that period. Conception occurred in the Brahman cross only after the calf was weaned, and the cow was gaining weight.

The average body weights of the buffalo and Brahman cross cattle at Urimo were about 360 and 300 kg, respectively. At Erap average live weights for both species were about 420 kg. The higher fertility of the buffalo at Urimo was possibly related to their higher mean body weights. The mature live weights of the Javanese Zebu ranged from 250-350 kg.

A survey of five smallholder cattle farms in P.N.G., carrying Brahman cross cattle grazing predominantly kunai (*Imperata cylindrica*) pastures (Holmes *et al.* 1976), showed that the calving percentage of 69 heifers with mean live weights from 312-364 kg ranged from 62-100%. The calving percentage of 114 mature cows in the same study with live weights from 341-417 kg ranged from 75-100%. The wide range in calving percentages is probably more related to environmental conditions rather than genotype.

Basilio (1980) studied calving percentages in the Passam area of the East Sepik Province in P.N.G., and compared two management systems on smallholder farms. The study found that paddock grazing and herding systems had calving percentages of 75 and 71% respectively.

In Solomon Islands, Freeman (1981) reported pregnancy rates of small numbers of Brahman cross heifers at 80-95% in the government herd at Tenavatu.

The reproductive performance of the Brahman cross cattle grazing at the Cattle Under Trees Project (C.U.T.), Kolombangara was reviewed (Schottler *et al.* 1984). The project is situated on free-draining basalt-derived soils of low phosphate status. There are 1500 ha of pastures under *Eucalyptus deglupta* trees, and *Paspalum conjugatum* is the dominant grass species. There is approximately 400 ha of open pasture of signal grass (*Bracharia decumbens*) and Koronovia grass (*Bracharia humidicola*). The main legumes are *Centrosema pubescens* and *Pueraria phaseoloides*. The total number of Brahman cross cattle is 2600 head.

Pregnancy diagnosis of 283 heifers and cows in 1981 indicated a pregnancy rate of 62.5%. Non-pregnant lactating cows comprised 29.0%, and non-pregnant non-lactating cows 8.5% of the animals tested. An analysis of pregnancy diagnoses of 292 cows and heifers during the period 1980-82 can be summarized as follows: The pregnancy rate of the first test was 64.4%; the proportion of animals with two successive pregnancies 12 months or less apart, was 42.6%. The proportion of cows that showed post-partum anoestrus was 44.3%, although some of these animals could have been infertile. Where seasonal joining is practised at C.U.T., the maximum pregnancy rate is 64.8%.

Table 2 shows the mean live weights and pregnancy rates of heifers at C.U.T. during the previous 3 years.

Table 2. Live weights and pregnancy status of heifers at C.U.T. The number of heifers is indicated in brackets.

	1980	1981	1982
Live weight-Pregnant (kg)	281.4 (94)	315.4 (58)	288.5 (427)
Live weight-Non pregnant (kg)	278.2 (23)	310.1 (8)	277.4 (125)
Proportion pregnant	80.3%	87.9%	77.4%

On a national basis the herd fertility in Solomon Islands is disappointingly low. Table 3 shows the percentage of calves compared with breeders in the national herd, according to herd size in 1981 and 1982.

Apart from the small herds, fertility is not related to herd size. The ranch or plantation sector is unable to achieve a higher calving percentage than the smallholder sector.

The national herd turnoff in both countries is around 14% per annum, and it is likely that a similar herd fertility situation exists in Papua New Guinea.

Table 3. Solomon Islands herd fertility.

Herd Size	Calving percentage 1981	Calving percentage 1982
1-10	40.0	39.0
11-20	48.9	51.6
21-50	50.0	54.7
51-100	51.7	44.6
101-500	47.9	48.6
Over 500	44.7	48.6
Total	46.2	48.6

Source: Extracted from Cattle Development Authority Annual Reports 1982 and 1983.

Live weight Gains

The live weight gains of animals will influence age at first conception and slaughter weights. Live weight gains are mainly influenced by environmental conditions, but there are also breed and species differences.

Table 4 shows the pre-weaning live weight gains of Brahman cross, Javanese Zebu, and water buffalo at Erap and Urimo.

Table 4. Pre-weaning growth rates: Papua New Guinea.

Location	Breed/Species	Average daily gain (kg/day)
Erap:	Javanese Zebu	0.50
	Buffalo	0.56
	Brahman cross — Herd A	0.72
	Brahman cross — Herd B	0.72
Urimo:	Javanese Zebu	0.53
	Buffalo	0.49
	Brahman cross — Herd C	0.35
	Brahman cross — Herd D	0.46

(After Holmes *et al.* 1974).

While the Brahman cross cattle performed well in the improved environment at Erap, their growth rates were much slower under the harsh conditions at Urimo. The growth rates of the Javanese Zebu cattle and the buffalo were similar in each environment.

The growth rates of Brahman cross cattle grazing *Imperata* dominant pastures on five smallholder farms in P.N.G. is shown in Table 5.

Table 5. Growth rates of Brahman cross cattle on smallholdings, Papua New Guinea.

Class of animal	Daily liveweight gain (kg/day)	No. of head
Female calves to 9 months	0.30-0.60	92
Heifers to first conception or 2 years of age	0.27-0.39	66
Male calves to 9 months	0.40-0.69	118
Steers to 450 kg	0.26-0.46	176

(After Holmes *et al.* 1976).

The stocking rate varied from 0.28-0.77 beasts/ha, although there was no clear relationship between growth rate and stocking rate. Differences in soil type and rainfall made any such comparison meaningless.

The post-weaning live weight gain of Brahman cross calves weaned at 4-7 months ranged from 0.20-0.32 kg/day at Erap (Schottler and Williams 1977) and was not related to age at weaning.

Schottler (unpublished) obtained satisfactory live weight gains at Erap with Brahman cross steers grazing a buffel grass (*Cenchrus ciliaris*)/legume pasture at three stocking rates during a period of 26 months. Average daily live weight gains at stocking rates of 0.87, 1.25, and 2.5 steers ha^{-1} were 0.61, 0.60, and 0.53 kg/day, respectively.

There is a considerable amount of information available in Solomon Islands on cattle growth rates for different pasture types at different stocking rates. At increasing stocking rates, gains per head decrease, although gains per hectare increase and then decline as illustrated in Table 6.

Table 6. Cattle growth rates, Guadalcanal.

Pasture	Stocking rate (an/ha)	Average daily gain (kg)	Kg/yr	Kg/ha/yr
B. mutica	1.8	0.57	209	376
	2.7	0.56	204	551
	3.6	0.44	162	583
	4.5	0.34	124	558

(After Watson 1977).

Freeman has reported post-weaning live weight gain in bulls up to 0.82 kg/day at Tenavatu. Cattle on stocking rate trials on improved and natural pasture under coconuts (Watson and Whiteman 1978) have shown live weight gains of the order of 0.33-0.50 kg/day.

At the Cattle Under Trees Project (C.U.T.), Gutteridge (pers. comm.) reported daily live weight gains on improved pasture under trees of 0.11-0.46 kg/day at stocking rates of 2.0 beasts/ha. There has been a gradual decline in live weight gain with time, possibly reflecting declining soil fertility and pasture deterioration.

The results of an analysis of the live weight gains of heifers at C.U.T. during 1980-81 showed that mean live weight gains ranged from 0.18-0.23 kg/day. There was comment that the project was overstocked during this period at 1.1 beasts/ha on pastures under young *Eucalyptus deglupta,* although mineral deficiences etc. cannot be ruled out. During long wet periods live weight gains declined to very low levels.

Daily live weight gains of weaner steers at C.U.T. grazing open improved pasture averaged 0.43 kg/day during a period of 4 months.

Conclusions

The disappointingly low reproductive rates of Brahman cross cattle under the adverse conditions experienced in the region indicate that Brahman cross cattle are probably not the most suitable large ruminant for hot humid environments. In the drier more favourable environment of the Markham Valley, P.N.G., Brahman cross cattle show superior performance to the buffalo and Javanese Zebu cattle.

However, high levels of managerial skill and resources are required to obtain and sustain high productivity and in the foreseeable future such productivity is unlikely. Ruminants in this region will continue to rely on overstocked pastures, often of poor quality.

Alternative breeds such as the Javanese Zebu cattle that have demonstrated higher fertility and superior overall productivity under harsh conditions should be investigated by themselves and in cross breeding programs with, for example, Droughtmaster or Africander cattle. A long-term commitment is required for the work. In wet swampy areas where cattle are not suited, the water buffalo would seem to be worthy of consideration.

It seems doubtful that the heavy promotion of large ruminants is justified in view of the very low returns being experienced compared with other crops. The promotion of cattle into cleared rain-forest is a doubtful environmental undertaking. Cattle have a place under coconuts and in some agroforestry systems. Apart from areas of very poor grassland such as the Sepik Plains and some highland areas of P.N.G., cattle should be seen as part of an integrated farming system. There are land tenure and social considerations that must also be taken into account in this region.

Alternative smaller ruminants such as sheep or goats may be more suitable than large ruminants. However, it is of vital importance that they be properly evaluated before proceeding with large scale development.

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Appendix Table 1. Distribution of cattle by ownership 1967-82 — Solomon Islands.

Year	Plantation		Mission		Sol. Islanders		Government		Total	
	Herds	Cattle	Herds	Cattle	Herds	Cattle	Herds	Cattle	Herds	Cattle
1967	21	7160	33	883	97	661	5	82	156	8786
1970	31	9697	31	1024	212	1222	6	156	280	12099
1971	23	10538	32	1236	246	1574	7	306	302	13654
1972	21	11933	31	1328	278	1846	8	691	338	15798
1973	20	12549	32	1560	338	2564	7	519	397	17192
1974	24	13144	35	1529	502	4618	13	1937	574	21228
1975	26	12023	36	1751	577	6859	11	2035	650	22668
1976	27	11875	39	1902	688	8723	14	1610	768	24110
1977	30	11553	36	1634	712	9786	12	1803	790	24775
1978	31	12006	36	1331	747	9441	16	2407	828	25185
1979	36	10390	33	1217	738	9059	17	1918	823	22584
1980	29	9134	38	1236	737	8723	19	3902	823	22995
1981	23	8279	32	1075	711	9014	21	4968	787	23336
1982	21	7279	32	1018	723	9761	22	5613	799	23671

(Plantation, Mission, Sol. Islanders and Government are grouped under "Ownership".)

Appendix Table 2. Composition of herd by size of herd 1982 — Solomon Islands.

Size of Herd	No. of Herds	Herd % of total	No. of cattle	Cattle % of total
1 - 10	438	54.8	2 389	10.1
11 - 20	183	22.9	2 852	12.0
21 - 50	123	15.4	3 378	14.3
51 - 100	34	4.3	2 128	9.0
101 - 500	16	2.0	3 198	13.5
Over 500	5	0.6	9 726	41.1
Total	799	100.0	23 671	100.0

Source: Cattle Development Authority, Annual Report 1983.

Appendix Table 3. Estimated cattle population, Papua New Guinea, June 1976.

	Smallholders		Ranch[a].		Total	
Province	Units	Cattle No.	Units	Cattle No.	Units	Cattle No.
Western	15	174	8	606	23	780
Gulf	43	418	9	365	52	783
Central	184	2 238	32	10 612	216	12 850
Milne Bay	174	2 100	20	3 470	194	5 570
Northern	238	5 864	3	3 947	247	9 811
S. Highlands	436	2 952	22	1 693	458	4 645
Enga	288	1 412	8	330	296	1 742
W. Highlands	140	1 500	23	9 258	163	10 758
Chimbu	254	2 413	3	500	257	2 913
E. Highlands	347	7 100	23	6 473	370	13 573
Morobe	1 040	12 000	25	43 225	1 065	55 225
Madang	151	3 697	13	11 354	164	15 051
E. Sepik	370	5 350	16	4 882	386	10 232
W. Sepik	148	1 048	2	353	150	1 401
Manus	3	30	3	109	6	139
New Ireland	6	92	15	2 186	21	2 278
E.N. Britain	4	51	15	2 098	19	2 149
W.N. Britain	8	121	8	885	16	1 006
N. Solomons	61	903	20	953	81	1 856
Total	3 910	49 463	268	103 299	4 178	152 762[b]

Source: Densley, D.J.R. 1978. Livestock *in* Agriculture in the Economy. Department of Primary Industry, P.N.G.

Notes: a. Includes Government, plantation, and mission herds.

Breed Evaluation of Large Ruminants in Indonesia

Wartomo Hardjosubroto*

THERE are several breeds of cattle in Indonesia, namely Bali, Madura, Ongole, and Grade Ongole.

Bali cattle are descendants of the indigenous Banteng (*Bos sondaicus*). They have been developed through a long domestication period. They are maintained as a pure breed on Bali island.

Madura cattle represent a distinct breed, and are thought to have originated from a cross between Banteng and indigenous cattle, which descended from types introduced by early traders.

Ongole cattle are a pure breed in Indonesia, descended from cattle imported from India in 1914, and these remain as purebred cattle in Sumba Island. The Grade Ongole cattle or the 'Peranakan Ongole' originated from crossing between Ongole cattle and local Javanese cattle.

The main purposes of these cattle are to supply draught animals and farm manure. In addition, all cattle produce beef and hides. In most areas, cattle are kept in stalls and fed cut grasses, food crops residues, and other feeds. Some cattle are allowed to graze the natural grassland in the vicinity of the village, road sides, playgrounds, idle farm land, etc.

The dominant mating system of cattle in Indonesia is natural mating. However AI for beef cattle was introduced in 1974 and is becoming more popular. Grade Ongole cattle are first used for breeding when about 2.8 years old(Hardjosubroto and Sudiono 1975). The age at first parturition in Bali cattle under ranching conditions is 857 $\pm$ 137 days (Sumbung *et al.* 1978), while in Grade Ongole under village conditions it is 41-47 months (Hardjosubroto and Sudiono 1975).

Bali cattle show a seasonality of oestrus, 66.0% showing oestrus between August and January (Pastika and Darmadja 1976), and 70.9% of the births occurring between May and October. Ongole cattle apparently show no seasonality of oestrus or births.

Sumbung *et al.* (1978) found that the interval between parturitions in Bali cattle under ranch conditions was 388 $\pm$ 61 days; however, Darmadja and Sutedja (1976) found the interval was 528 $\pm$ 155 days for Bali cattle kept in villages. Figures for Grade Ongole cattle were 19 months (Hardjosubroto and Sudiono 1975).

Daily gains of Bali cattle and Grade Ongole cattle were 0.35-0.50 and 0.12-0.30 kg, respectively (Anon 1975). When a concentrate feeding system was used, Moran (1978) found that the daily gains of Bali, Madura, and Ongole cattle were 0.66, 0.60, and 0.75 kg, respectively.

Most of the buffaloes in Indonesia are the swamp type, while in North Sumatra there are some of the dairy type, the Murrah breed. The swamp buffaloes are used primarily for work in ricefields, but some are used for pulling carts. In South Sulawesi, some swamp buffaloes are milked. Buffaloes are usually found in swampy areas, especially the rice producing areas, which usually have a high annual rainfall. However, buffaloes are also found in Nusatenggara, where the season is dry for 7-8 months a year. The mating system in swamp buffalo is natural mating. In only a small number of buffaloes in West Java and South Sulawesi has AI been tried.

The total number of beef cattle in Indonesia in 1982 was 6 594 000 (Anon 1983). Most of them are Grade Ongole. Bali cattle numbered about 600 000 and Madura cattle about 500 000. During 1969-1978, the total number of beef cattle decreased at a rate of 0.18-0.19% a year. This was due to the increasing number of animals slaughtered, high mortality, and low calving percentage. Many attempts have been made to solve this problem, e.g. disease control, extension of AI, and importation of cattle.

Since 1980, many cattle have been imported to Indonesia, especially from Australia. They were Brahman, Brahman cross, Droughtmaster, Santa Gertrudis, and some Sahiwal cross. These cattle were distributed to the farmers. Some of these cattle were used in ranching, but most of them are kept under a traditional management system, with stall feeding. So, these cattle had to face two kinds of adaptations, firstly adaptation to the climatic and environmental

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differences, and secondly to the management differences. Besides the importations by the government, there are also many cattle imported from Australia by private ranchers.

For developing good breeding programs and evaluating the government programs to improve the genetic quality of beef cattle, more preliminary base line information is needed on local and imported cattle. This research has as its objective the accumulation of this kind of data from native and imported cattle, under two different management systems, traditional and ranching. Base line information on water buffaloes will also be accumulated.

Materials and Methods

This breed evaluation will be divided into two kinds of management systems (traditional and ranching), with two kinds of cattle (native and imported), as follows:

1. (a) The productivity of local cattle (Grade Ongole) raised under the traditional management systems;
   (b) The productivity of native (Ongole, Bali, and Grade Ongole cattle) and imported cattle (Brahman cross) under ranching conditions;
   (c) The productivity of imported cattle under the traditional system.
2. The productivity of water buffaloes.

Data to be observed are especially on reproductive performance and mortality.

1. (a) The productivity of local cattle raised under the traditional system by farmers

Two thousand local cattle (Grade Ongole) were studied in two districts at Yogyakarta, Java. All animals were identified and each was under the observation of a member of one of the cadres, who recorded observations on special cards. Each member of a cadre supervised observations on 50 cows and data were collected every two weeks. This research was carried out from July 1977 until June 1981, and the items observed included reproductive data and mortality.

1. (b) The productivity of native and imported cattle under ranching conditions

This study was done in South Sulawesi, using 2200 cattle. The Brahman, Brahman cross, and Droughtmaster cattle were imported from Australia, and used to be called the Australian cattle or just the Brahman cross cattle. The native cattle consisted of Ongole, Bali, and Grade Ongole breeds. Each mating group was in a separate paddock. Observations on reproductive performance, mortality, and body weights were recorded from July 1977 to December 1983.

1. (c) The productivity of imported cattle raised under the traditional system by farmers

In 1980-1981, about 37 000 cattle were imported from Australia by the Government. These cattle were mostly Brahman cross, and the rest were Droughtmaster, Santa Gertrudis, and Sahiwal cross. They were distributed to the farmers as a loan, the terms of which are given in the Appendix. The information to be presented here on reproduction and mortality was based on a survey in April and December 1983 in 12 provinces. In each province, 200 farmers were taken as samples.

2. The productivity of water buffalo

Data were based on a survey in December 1982 in 7 provinces that are the most dense in buffalo production in Indonesia. One hundred farmers were selected in each province. Data are especially on reproductive performance and mortality.

Results and Discussion

1. (a) The productivity of local cattle raised under the traditional system

The local cattle of the farmers in Yogyakarta are mostly Grade Ongole. They are kept in stalls and fed cut grasses and leaves. Many animals are fed rice straw, maize crop residues, and sugar cane tops. These cattle are used primarily for work in ricefields.

The calving percentages found in this study are shown in Table 1. Calving percentage was calculated from the total number of calves born each year as a percentage of mature cows.

The calving percentages were consistently low, averaging 36.0%. Koestono (1977) in his study in the same region found the calving percentage in 1976-77 in the lowland area of Yogyakarta to be 23.77%, while in the mountain area it was 30.33%.

This distribution of calves born throughout the year is given in Table 2. The percentage of calves born during the period April-September was 61.48%.

This was due to management factors. The percentage of all births that were females in this study was 54.2% (Hardjosubroto *et al.* 1981a), within the normal range.

Table 1. Calving percentage of Grade Ongole cattle at Yogyakarta.

Period	Calving %
1978-1979	43.42
1979-1980	34.40
1980-1981	30.18
Average	36.00

Source: Hardjosubroto *et al.* 1981a.

Data on services per conception (s/c) can be calculated on only 241 cows that became pregnant in 1978 and 1979, and the result was: 1978 s/c = 1.34 and 1979 s/c = 1.40, with the average being 1.37. The rate of 1.37 was in the normal range.

During the 4 year study in the location, 75 cows out of 2000 were identified as having reproduction problems. Upon examination by rectal palpation, 61 cows were found to have normal reproductive organs, and only 14 cows (0.7%) were found to have abnormalities such as unilateral or bilateral ovarian sub-function, persistent corpus luteum, or luteal cysts. It appears that reproductive failure in female cattle in the area studied may be caused largely by management factors, but hereditary factors should also be considered (Sutimbul *et al.* 1981).

Table 2. The distribution of calves born throughout the year at Yogyakarta.

Period	1978 (%)	1979 (%)	1980 (%)	Average (%)
Jan.-Mar.	10.00	21.78	26.13	19.30
Apr.-Jun.	35.72	31.09	29.04	31.95
Jul.-Sep.	33.10	25.82	29.66	29.53
Oct.-Dec.	21.18	21.31	15.17	19.22

The annual mortality for cows and calves is given in Table 3. The cow mortality was calculated based on the numbers of adult cows, while calf mortality was based on the number of calves born each year.

A part of the mortality of cows was due to poisoning, and most of the calves died due to weakness.

Table 3. Mortality of cows and calves in each year.

Year	Adult cows (%)	Calves (%)
1978	1.46	1.12
1979	3.39	0.42
1980	2.50	1.20
1981	3.33	1.34
Average	2.67	1.02

Source: Hardjosubroto *et al.* 1981a.

Determination of weaning age here was rather difficult because there are differences in the meaning of 'weaning age' among the farmers. For most farmers, weaning age means the age at the time calves are separated from their mothers, but separation sometimes occurs only at the time when the calf is already big enough to be sold, or when the farmers need money. The average age at weaning was 241.4 days, or about 8 months (Hardjosubroto *et al.* 1981a). Koestono (1977) found the weaning age of native cattle at Yogyakarta was 8.75 months in lowland areas and 11.08 months in the mountain areas. Hardjosubroto and Sudiono (1975) obtained a value of 10.9 months in Central Java.

Results of serum and faecal examinations are presented in Table 4.

Table 4. Blood serum and faecal examinations for disease investigation on Grade Ongole cattle at Yogyakarta (1983).

Total number of samples	:	320
Result on blood serum examination		
(a) Brucellosis (%)	:	0
(b) *Pasteurella* (%)	:	0
Result of faecal examination		
(a) Negative (%)	:	27.3
(b) Positive (infected by worms)	:	72.7
— liver fluke (%)	:	22.7
— coccidia (%)	:	13.6
— strongyle (%)	:	54.5

Source: Djaroebito 1983.

The results show that there were no reactors for brucellosis and *Pasteurella* in the native cattle (Grade Ongole) located at Yogyakarta, in 1983. There were

72.7% of the cattle that were infected by intestinal worms, and most of them were infected by strongyles (54.5%).

1. (b) The productivity of native and imported cattle under ranching conditions

Many ranches can be found in South Sulawesi. This research was conducted at one of the best ranches in South Sulawesi, which imported cattle from Australia over recent years. There were also some Ongole cattle coming from Sumba Island, and Bali and Grade Ongole cattle from surrounding places. The imported cattle from Australia are known as the 'Australian cattle' or 'Brahman cross' cattle. In this study, the term Australian cattle will be used.

The percentage of calves born each year is presented in Table 5.

Table 5. Calving percentage.

Breed	1978	1979	1980	1981	1982	1983	Average
Australian	44.35	42.35	36.75	37.9	53.27	30.81	40.91
Ongole	44.28	25.67	50.07	44.7	56.79	43.24	44.13
Bali	43.22	26.66	45.95	36.3	61.92	28.37	40.42
Grade Ongole	—	—	—	—	64.89	44.98	54.94
Average	43.98	31.56	44.26	39.63	59.22	36.85	45.10

Source: Hardjosubroto *et al.* 1981a,b, 1983a,b.

Although calving percentages of Grade Ongoles were obtained only in two years, they showed a better result (54.94%) than the other breeds. The calving percentage of the Australian, Ongole, and Bali cattle were almost the same.

Data on calf mortality, as a percentage of the calves born each year, and cow mortality, as a percentage of adult cows, are presented in Table 6. Results on mortalities in the period 1977-1981 could not be calculated separately for each breed.

Most cases of cow mortality were due to weakness, dystocia, or accident, while most cases of calf mortality were deaths shortly after birth or deaths associated with diarrhoea or weakness. An average calf mortality of 4.39% and a cow mortality of 1.79% are in a normal range.

Table 6. Calf and cow mortality.

Breed of cow	1982	1983	Average
	Calf mortality %		
Australian	3.61	8.25	5.93
Ongole	3.57	6.71	5.14
Bali	2.74	8.33	5.54
Grade Ongole	0.57	1.33	0.95
Average:			4.39
	Cow mortality %		
Australian	2.98	2.85	2.92
Ongole	2.64	1.40	2.02
Bali	1.48	1.21	1.35
Grade Ongole	1.28	0.46	0.87
Average:			1.79

From Tables 5 and 6, it can be seen that Grade Ongole cattle showed better calving percentages and fewer mortalities than the other breeds.

The uncorrected weaning weights are shown in Table 7. The exact weaning ages of the calves were not known but were about 8-9 months.

Table 7. Live weight (kg) of calves at weaning (mean ± s.d.).

Breed	Male	Female	Average
Australian	141.5 ± 20.5 (89)	138.3 ± 19.1 (83)	139.9 ± 20.1 (172)
Ongole	150.4 ± 23.6 (36)	147.9 ± 24.2 (39)	149.1 ± 23.7 (75)
Bali	138.3 ± 30.8 (26)	126.7 ± 10.4 (23)	134.4 ± 25.6 (49)
Grade Ongole	145.0 ± 20.0 (33)	125.8 ± 19.6 (26)	132.2 ± 20.8 (59)

Source: Hardjosubroto *et al.* 1983a, b.

Note: Numbers in brackets are the total number of calves observed in each group.

Ongole calves showed the highest weaning weights.

Due to the difficulties in obtaining birth dates and birth weights, the pre-weaning daily gains were calculated from two consecutive weighings before weaning in February and June. The calculated average daily gains of pre-weaning calves are shown in Table 8.

Table 8. Average daily gains of pre-weaning calves (kg/day).

Breed	Number of calves	Average daily gain
Australian	34	0.38
Ongole	24	0.37

Source: Hardjosubroto *et al.* 1981b.

The Australian and the Ongole calves showed the same level of average daily gain. These daily gains were obtained on native pasture.

Post-weaning gains were calculated also from two consecutive weighings in May and October 1980. The calculated gains of weaners reared on native and improved pastures are shown in Table 9.

Table 9. Post-weaning daily gains of calves on native and improved pastures (kg/day).

Breed	Native pasture		Improved pasture	
Australian	0.09	(89)	0.41	(70)
Ongole	0.16	(83)	0.42	(43)
Bali	0.19	(44)	0.28	(30)

Source: Hardjosubroto *et al.* 1981b.

Note: Numbers in brackets are the total numbers of weaners observed in each group.

Another study of post-weaning gain in January-April 1983 used two different feeding management procedures, namely (a) native pastures + concentrate feeding, and (b) improved pasture. The concentrate feeding consisted of 300-400 kg of rice bran given daily to the whole group during the period of 3 months. The result of the experiment is shown in Table 10.

From Tables 9 and 10 it can be seen that on native pasture the Australian cattle showed poor daily gain, but with concentrate feeding and on improved pasture, the Australian cattle showed better daily gains than native calves.

Results of blood and faeces examinations are shown in Table 11.

Four Bali cows and 2 Grade Ongole cows showed a positive reaction to the brucellosis test. Bali cattle showed the highest proportion of reactors to *Pasteurella*. No Ongole cattle were infected by brucellosis or *Pasteurella.*

Table 10. Post-weaning daily gains of steers 10-12 months of age (kg/day).

Breed	Native pasture + conc. feeding	Improved pasture
Australian	0.28 $\pm$ 0.08 (87)	0.32 $\pm$ 0.10 (121)
Ongole	0.25 $\pm$ 0.09 (68)	0.24 $\pm$ 0.14 (47)
Bali	0.24 $\pm$ 0.04 (19)	0.28 $\pm$ 0.08 (20)
Grade Ongole	0.26 $\pm$ 0.02 (20)	0.29 $\pm$ 0.05 (25)

Source: Hardjosubroto *et al.* 1983a,b.

Note: Numbers in brackets are the total number of steers observed in each group.

Table 11. Results of blood serum and faeces examinations (November 1983).

Total number of sample		
Australian	:	66
Ongole	:	30
Bali	:	30
Grade Ongole	:	22
Result on blood serum examination		
	Brucellosis (%)	*Pasteurella* (%)
Australian	0	18.2
Ongole	0	0
Bali	13.3	26.7
Grade Ongole	9.1	18.2
Result of faeces examination		
Percentage of cattle infected with intestinal worms (%)		
Australian	84.8	
Ongole	66.7	
Bali	33.3	
Grade Ongole	54.5	

Source: Djaroebito 1983.

1. (c) The productivity of imported cattle raised under a traditional system

In 1980-1981, a total of 37 867 cattle consisting of 4 148 males and 33 719 females, were imported from Australia. These cattle were mostly Brahman cross, and the rest were Droughtmaster, Santa Gertrudis, and Sahiwal cross cattle. They were distributed to the farmers as a loan.

Data presented here are based on a survey done in April and December 1983.

The reproductive performance of imported cattle raised under traditional management by farmers was very low (see Table 12). The overall calving percentage of all breeds in 1983 was only 28.6%, and 26.1% of the cows were in a pregnant condition in December 1983. The calving percentage of Sahiwal cross in West Java seemed to be at a moderate level (58.8%). On the other hand, the calving percentages of Brahman cross, Santa Gertrudis, and Droughtmaster were very low (24.1%, 23.5%, and 35.4%, respectively). The numbers of cows that had given no birth since the distribution of the cattle were 57.2%, 45.3%, 33.3%, and 28.6%, for Brahman cross, Santa Gertrudis, Droughtmaster, and Sahiwal cross respectively.

Table 12. Reproductive performance of imported cows raised under a traditional system by farmers.

Breed	Province	Cows that have given birth (%)			Calving percentage in 1983 (%)	Pregnant cows Dec. 1983 (%)
		0X	1X	2X		
BX	Cent. Java	57.8	38.6	3.6	21.1	18.3
	East Java	64.2	30.4	5.4	28.6	(?)
	East Nusateng.	58.3	41.7	0	17.5	46.8
	Yogyakarta	80.4	19.6	0	11.2	20.9
	Lampung	33.8	54.9	11.2	42.6	31.5
	Aceh	61.6	29.9	8.5	(?)	12.7
	West Kalimantan	73.8	23.8	2.5	6.0	7.5
	East Kalimantan	27.6	62.8	9.6	41.5	38.7
	Average:	52.7	37.7	5.1	24.1	25.2
SG	Lampung	45.3	54.7	0	23.5	16.9
DM	Maluku	33.3	59.0	7.7	35.4	25.4
SX	West Java	28.6	71.4	0	58.8	42.2
Overall average:		51.4	44.3	4.4	28.6	26.1

Source: Anon. 1984.

Note: BX = Brahman cross; SG = Santa Gertrudis; DM = Droughtmaster; SX = Sahiwal cross.

*OX = Cows not calved; 1X = Cows with one calf; 2X = Cows that have calved twice.

The reason is still unknown, but it seems that management and feeding were important factors. These cattle were raised on ranches in Australia, but now most of them are in stall-feeding conditions. This system has an influence on breeding management, because the farmers have to bring the cows to the bulls when in oestrus. The change from an extensive to a stall system involves problems in cattle handling.

Table 12 shows that the percentages of cows that have given birth during the 32 months from distribution up to December 1983 were 42.8%, 54.7%, 66.7%, and 71.6% for BX, SG, DM, and SX, respectively. So, the calving percentage within 12 months can be calculated as follows : BX = 16.1%, SG = 20.5%, DM = 25.0%, and SX = 26.9%. The results in 1983 represented an improvement on these averages.

From Table 13 it can be seen that 37.8% of the cows have never become pregnant, and 31.4% of the bulls were inactive. Most of the bulls showed no libido. The highest percentages of infertile cattle were among Brahman cross and Santa Gertrudis. Most of the infertile cows had failed to show oestrus.

Table 13. The percentage of infertile cattle to December 1983.

Breed	Province	Infertile cows (%)	Inactive bulls (%)
Brahman cross	Centr. Java	44.1	36.4
	East Java	46.4	10.0
	East Nusatenggara	34.6	15.0
	West Java	14.3	(?)
	Yogyakarta	79.1	95.7
	Lampung	31.9	0
	West Kalimantan	73.8	92.0
	East Kalimantan	12.7	15.4
	Average	42.1	37.8
Santa Gertrudis	Lampung	44.0	33.3
Droughtmaster	Maluku	17.2	9.1
Sahiwal cross	West Java	18.2	7.1
Overall average		37.8	31.4

Source: Anon. 1984.

Feeding has an important effect on reproductive performance of cattle. In this survey (Anon. 1984), it was found that 60.2% of the farmers feed their cattle with native grass only, and 39.8% of them apply concentrate feeding (Table 14). Most of the concentrate feeding was only with rice bran.

Table 14. Feeding management.

Breed	Province	Grass only (%)	Grass + conc. feeding (%)
Brahman cross	Centr. Java	66.1	33.9
	East Java	28.5	71.5
	East Nusatenggara	100.0	0
	Yogyakarta	96.2	3.8
	Lampung	52.4	47.6
	Aceh	17.5	82.5
	West Kalimantan	99.5	0.5
	East Kalimantan	55.3	44.7
Santa Gertrudis	Lampung	52.4	47.6
Droughtmaster	Maluku	85.7	14.3
Sahiwal cross	West Java	9.0	91.0
Overall average		60.2	39.8

Source: Anon. 1984.

In West Java 91.0% of the farmers who manage the Sahiwal cross cattle practised concentrate feeding. It can be suggested that the good performance shown by the Sahiwal cross was not a breed effect, but could be due to better feeding.

Finally, it can be reported that 1940 of the cattle (18.43%) had died since their distribution and 102 of their calves (7.28%). Unfortunately the annual mortality based on breed could not be calculated.

The percentage of abortion found in this study (Anon. 1984) was 0.06% of the total number of adult cows, and most of the abortions happened in East Java.

2. The performance of water buffalo in Indonesia

The Indonesian water buffalo (*Bubalus bubalis*) is spread throughout the country. The total population in 1982 was 2 513 000. Most are swamp buffaloes, and only about 2% are dairy type (Anon. 1983). According to the statistical report, the natural increase of the water buffalo in Indonesia was 10.10% in 1976, 10.75% in 1978 (Anon. 1983), and in 1979-1982, the population increased an average of 2.12% per year.

Data presented below are based on a survey in December 1982.

The calving percentage and the mortality of water buffalo in Indonesia are presented in Table 15. The calving percentage was calculated based on the total number of adult female buffaloes, while mortality was based on the total number of the population.

Table 15. The calving percentage and mortality of water buffalo in Indonesia in 1982.

Province	Calving %	Mortality %
Aceh	75.10	4.80
West Java	55.38	7.07
Central Java	49.67	1.60
East Java	42.95	4.40
West Nusatenggara	67.25	7.30
East Nusatenggara	53.15	19.30
South Sulawesi	39.33	7.20
Average:	54.69	7.38

Source: Hardjosubroto *et al.* 1983,a,b.

The calving percentage found in this study was 54.69%. Since the percentage of the adult female buffaloes to the total population was 45.09% (Hardjosubroto *et al.* 1983), it can be calculated that the calving percentage based on the whole population was 24.55%. With the average mortality of 7.38%, it can be said that the natural increase was 17.28%.

Data on the age at first calving and calving interval are presented in Table 16.

Table 16. Data on age at first calving, calving interval, and age at culling of female water buffaloes in Indonesia.

Province	Age at first calving (year)	Calving interval (month)	Age at culling (year)
Aceh	3.6	21.0	8.1
West Java	4.1	20.3	13.0
Central Java	3.9	18.9	10.1
East Java	4.1	21.4	11.6
East Nusatenggara	3.8	18.0	11.6
West Nusatenggara	3.6	18.8	11.7
South Sulawesi	4.1	21.6	13.4
Average	3.88	20.00	11.36

Source: Hardjosubroto *et al.* 1983,a,b.

The age at first calving was 3.88 years. The average culling age was 11.36 years. With the average calving interval of 20.0 months, it can be calculated that the female buffaloes had an average lifetime production of 4.5 calves.

Conclusion

The productivity of the native cattle of Indonesia is low. The low calving percentage is a major factor. Management has an important role in the productivity of these cattle.

The productivity of the imported cattle (Australian cattle) raised under the traditional system was very low. There was evidence that these cattle needed time for adaptation. With better feeding and management, the productivity of these cattle can be improved. The farmers who will raise imported cattle should be a selected group.

The productivity of the water buffalo in Indonesia is at a moderate level.

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Appendix

The breeding policy on the development of imported cattle in Indonesia is to multiply the imported cattle, by distributing them among the farmers as a loan, with the following agreement:

1. Farmers who receive a pair of cattle should return 3 weaners (1.5-2 years old) within 5 years.
2. Farmers who receive one cow should return 2 weaners (1.5-2 years old) within 5 years.
3. Farmers who receive a bull, will own that bull after the production of at least 60 offspring.

All of the weaners mentioned above will be distributed to other farmers.

Evaluation Studies of Cattle in Indonesia

W.A. Pattie*, A. Winantea, and Nuryadi****

IN the densely populated regions of Indonesia there is evidence that cattle numbers are decreasing, probably in response to competition for land resources and reduced farm size. At the same time there is increased demand for meat and milk as urban populations increase. Development programs have aimed to increase beef production by enlarging the scale of cattle production in islands other than Java but there is considerable pressure on the traditional suppliers, Madura and Bali, to increase exports and slaughterings to meet the demand. Other avenues through which improvements could be made include improved reproductive efficiency and growth, reduction of deaths, and the control of wastage through culling and slaughter policies. In addition, milk production is also being stimulated in selected regions by the importation of dairy stock from Australia and New Zealand.

The construction of efficient development programs for achieving these aims through breeding methods requires a knowledge of the productivity levels and population dynamics of the target population. In addition, if animals are to be introduced from other populations as part of the improvement program, then the relative productivity of the existing and introduced animals must also be evaluated. This report presents the preliminary results of a study designed to examine the net reproduction rate of Madura cattle to provide a basis for the design of production improvement programs.

Population Dynamics of Madura Cattle

The Madura cattle of Indonesia are small, well adapted animals that are thought to derive from mixed Zebu and Banteng ancestry (Payne 1970). On the Island of Madura they form a closed population of approximately 600 000 animals, which are maintained for draught purposes, recreation (racing bulls), and beef production, with surplus stock being slaughtered or exported to Java.

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This study was carried out from September 1980 to July 1983 in two villages in the regency of Pamekasan, central Madura. The villages were Pamakasan and Pakong, which in 1981 supported 1129 and 3107 adult females, respectively. Animals that had been recorded by the regional Animal Husbandry Service were used. Visits were made to the villages each month for pregnancy diagnosis and to collect records of calvings, body weights, and stock movements. All animals had calved once and records relating to their age at first calving and the time between first calving and conception were obtained from the Animal Husbandry Service.

Animals Studied

Details of the animals involved in the study are given in Table 1.

Table 1. Numbers, ages, and body weights of cows in September 1980.

Village	Pamekasan	Pakong
Number	177	187
Age (mo)		
mean	45.6	44.7
range	34-59	32-58
Weight (kg)		
mean	233.6	234.3
sd	25.5	21.4

Reproductive Performance

Statistics relating to reproduction, calf birth weights, and mortality are given in Tables 2,3,4, and 5.

The levels of both peri- and post-natal mortality are relatively high and there is a slight relationship within calvings to birth weight. Mortalities were very high at the fourth calving and although the total numbers are small, they were consistent in the two villages. The high levels may be a feature of the age of the dams or they may have been caused by the prolonged and severe dry season of 1982-83.

Table 2. Calving performance of cows in each village (days).

Village	Pamakasan	Pakong
Number	161	166
Age at first calving		
mean	1 070	1 055
sd	91	115
Calving interval 1 – 2		
mean	450	455
Calving interval 2 – 3		
mean	433	443
sd	46	52
Calving interval 3 – 4		
mean	459	474
sd	56	59

Table 3. Birth weights (kg) of calves (std. dev. in brackets).

Village	Pamakasan	Pakong
Second calving		
Female	12.9 (1.8)	12.5 (1.8)
no.	96	86
Male	12.2 (0.8)	12.7 (1.1)
no.	81	101
Third calving		
Female	12.7 (1.3)	12.5 (1.3)
no.	87	85
Male	11.3 (0.7)	11.0 (0.8)
no.	79	85
Fourth calving		
Female	10.9 (0.7)	10.5 (0.7)
no.	22	11
Male	10.7 (0.7)	10.5 (0.8)
no.	25	14

Population Structure

The structure of a breeding population depends upon death rates and the culling and selling policies of the owner. No deaths were reported among the breeding cows during this study but cows were various times, mostly during the third pregnancy. Details sold of the stock sold are given in Table 6.

Table 4. Calf mortality (%) and birth weights (kg).

Village	Pamakasan		Pakong	
	dead %	birth wt.	dead %	birth wt.
Second calf				
1 week	9.0	11.6	8.6	11.7
3 months	7.9	11.9	10.2	12.4
Survivors	83.1	12.8	81.2	12.8
Third calf				
1 week	10.2	11.5	8.2	11.1
3 months	4.2	11.9	5.3	11.3
Survivors	85.6	12.1	86.5	11.8
Fourth calf				
1 week	23.4	10.4	32.0	10.4
3 months	23.4	11.2	12.0	10.0
Survivors	53.2	10.8	56.0	10.6

Table 5. Age and weight at first mating of heifers from the second calving.

Village	Pamakasan	Pakong
Number	47	25
Age (mo)		
mean	23.2	24.7
sd	2.4	2.5
Weight (kg)		
mean	169.1	173.1
sd	5.9	4.0

Table 6. Breeding cows sold during the study.

Village	Pamakasan	Pakong
Cows at start	177	187
Cows sold:		
Total	16	21
During 3rd preg.	11	16
During 4th preg.	5	5
Average age (mo)	63.9	63.8
sd	7.3	6.3

It is said to be normal for farmers to dispose of their breeding cows after the fourth calving and observations ceased in this study at that stage. To check this point, a survey was made of the ages of randomly chosen breeding cows in 20 villages of the regency of Pamakasan in May 1983. Records for this purpose were obtained from the regional Animal Husbandry Service. These show that only a very small proportion of cows are maintained after 7 years of age, which is the average age of weaning the fourth calf. The distribution of cows in each age group is given in Table 7.

Table 7. Age distribution of cows in 20 villages of the regency of Pamakasan.

Upper age limit (yr)	Percentage
1	18.1
2	12.9
3	11.4
4	13.5
5	14.5
6	12.6
7	13.2
8	3.7
Total number	325

Net Reproductive Rate

From the data presented here, it is possible to estimate the net reproductive rate of Madura cattle for the period under review. The data for each village were similar, so they have been combined for these estimates.

The time spent in the breeding herd was taken as the time between possible first mating and either sale or culling for age. The earliest first mating recorded was at 20 months, and if it is taken that cows are culled at 7 years, the breeding life is estimated as 5.33 years.

The average number of calvings per cow during her breeding life was 3.82 allowing for sales and culling. With the average calf death rate of 19% this resulted in an average of 3.1 calves weaned per cow-lifetime. As half the calves were females this represents a net reproductive rate of 1.55.

An estimate of the annual reproductive rate can be obtained by dividing the number of calves produced by the time in the breeding herd. This gives 72% for calves born and 58% for calves weaned.

Discussion

Because it was not possible to record the stock involved in this study throughout their whole life, some estimates had to be made on the basis of official records and extrapolations of pregnancy diagnosis data. However it is not likely that errors in these estimates would seriously bias the conclusions as calculations on a range of assumptions did not greatly alter the pattern of results.

Official statistics for the years 1977-1981 indicate that exports and slaughterings of Madura cattle have declined for the island as a whole, but not for the regency of Pamakasan. Projections based on these figures predict that output from Madura will decline to 54% of the 1977 figure by 1986. The results of this study indicate that such a decline is not due to poor reproduction under existing husbandry methods. The net reproductive rate of 1.55 indicates that the breeding population could be expanded and any decline in numbers arrested fairly rapidly even in the harsh conditions that prevailed during the study.

Although it is likely that the general decline in turn-off for cattle on Madura is related to the sale of breeding stock, there is room for improved biological efficiency. Calf mortality is high and post-calving anoestrus periods are long. These problems should respond to improved management procedures that take into account the need for adequate nutrition of pregnant cows during the extended dry season. The possible effects of draught work at this time should also be investigated.

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Review of Breed Evaluation Work in Ethiopia

Beyene Kebede*

ETHIOPIA, with a total land area of about 1.2 million km² is a vast country with varying agro-climatic conditions. Numerically, the cattle population is considered to be the largest (27 million) in Africa and amongst the top ten in the world. They are mainly of the Zebu type with some Sanga type existing in the east and north-eastern part of the country. With the large population size and the different agroclimatic conditions, cattle of different genetic types exist. The diversity in agroclimatic condition has also lend itself to various livestock production systems. Accordingly, two major livestock production systems can be identified with some intermediary types. These are the settled crop farming areas and the pastoralist areas.

The settled crop farming area covers the cultivated lands of the mid-altitudes and the highlands of the central, western, and south-western part of the country. It is estimated that it covers 55% of the country's total area and 92% of the human population, and 78% of the cattle population live here. It ranges in altitude from 1500 m to well above 2500 m and has a rainfall of above 700 mm/year. Since it is a major crop area, cattle are kept mainly to supply the draught power but at the same time, a small breeding herd is kept to replace the draught oxen and to provide the family with milk and butter. Draught oxen represent about 50-55% of the cattle population of the highland and breeding cows represent only 15-20%. In addition to providing power, draught oxen that are old and are no longer useful are sold in the market as meat animals. Cattle are also important because they provide farmyard manure, which is an important source of fuel and fertilizer.

The pastoralist area of the lowlands, which is arid and semi-arid with rainfall of less than 700 mm/year, is found mostly to the north-eastern, eastern, and south-eastern parts of the country. Although the area covers a high proportion (45%) of the country's area, only 8% of the human population and 22% of the cattle population live here. The people in this area are nomadic or semi-nomadic with large number of cattle. Unlike the cropping area, cattle are kept here mainly to supply milk and milk products, which is the basic diet of the people. As a result, a large proportion of the herd (80-85%) is females. Cattle in excess of family needs, and whenever there is need for cash, are sold for meat and usually such cattle are of better quality than the used oxen of the highlands.

Breed Evaluation Work

Breed evaluation work started in the country with the creation of agricultural training institutions, the Institute of Agricultural Research (IAR), and livestock development program under the Ministry of Agriculture. In all these institutions, the assessment of the production potential of the indigenous breeds as well as their improvement through crossbreeding has taken place.

At the College of Agriculture, a beef program was initiated in 1961 with Borana type cattle. The first phase was to study this type in its pure form and the second phase comprised crossbreeding with exotic breeds such as the Hereford, Aberdeen Angus, Charolais, Brahman, Santa Gertrudis, and Holstein-Friesian. Results on growth rate and feedlot performance as published by Wagner *et al.* (1969) show average birth weights of 21.6 kg and 26.0 kg, and weaning weights at 240 days of 135.9 kg and 166.4 kg for pure and crossbreds, respectively, and a feedlot performance of an average daily gain of 791 g/day for pure breds and 1090 g/day for crossbreds, as shown in Tables 1 and 2.

In addition to the beef work, the College has a dairy program where pure Friesian cows (mostly of Kenyan origin) and a small number of half- and three-quarter-bred Friesians are kept. The management and feeding level given to these cows was much superior and their milk yield was also found to be superior, in some cases even much higher than their place of origin. At present, breed evaluation work at the College is minimal due to a lack of personnel and space.

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Table 1. Birth weight and weaning weight (kg) of native Boran Zebu calves and crossbred calves at the College of Agriculture.

Breed	No	Birth	No	Weaning weight
Boran Zebu	38	22.3	38	138.6
Crossbreds	25	26.4	25	169.1

Table 2. Feed-lot performance of weight gain (kg/day) of Boran Zebu and crossbred cattle at the College of Agriculture

Breed	No	Weight gain
Boran Zebu	47	0.791
Crossbreds	31	1.091

The Institute of Agricultural Research has started its breed evaluation work by first assessing the different characteristics and production potential of three indigenous cattle types, namely Horro, Barka, and Borana. The assessment was made on growth rate, reproductive efficiency, and production potential for meat and milk. The program was carried out at four stations that represent different climatic and topographic conditions, and each cattle type was studied in the station that more or less represents its respective place of origin. Results from 6 years of research, although not very comprehensive, (Table 3) have indicated that the average yield of each of the three breeds does not exceed 700 kg of milk per lactation with a higher proportion of them giving not more than 100 kg. Only a small percentage gave more than 1500 kg.

Table 3. Gestation length (days), milk production (kg), and lactation length (days), of Barka, Borana, and Horro cows.

Observation	Barka (46)	Boran (19)	Horro (37)
Gestation length	294	—	285
Milk production:	675	494	559
Range	0-1 840	0-1 549	0-1 528
Best 25%	1 366	850	875
Lactation length	184	155	285

In the light of these findings, it was decided that it would be too big and too slow a task to improve the national average level of milk production by using our native Zebu breeds alone. A long-term crossbreeding research program was therefore proposed in 1974, the results of which it is hoped will offer guidelines for the kind of breeding policy to be followed in the future in the different agroclimatic conditions of the country.

The study was laid out in such a way that it would enable us to make contemporary comparisons among F_1 (local x exotic), F_2 (F_1 x F_1), and ¾ breeds (F_1 x exotic) alongside the pure-bred Zebus at the four stations representing different environmental conditions. The assessment is made on the effects of sire breed, dam breed, and genotype by environment interactions. Traits considered are growth rate, size, total dairy merit including milk yield, reproductive efficiency, viability, and disease resistance.

Whilst the improvement of the dairy traits is the primary objective, the beef aspect as an important by-product is also considered in the study. The indigenous breeds used are Barka, Borana, and Horro, on which some previous improvement programs have been undertaken, and the exotic breeds are Friesian, Jersey, and Simmental. It might be worthwhile at this point to mention why these three exotic breeds were chosen. The Friesian was chosen because it is the most widely accepted dairy breed in the world and it is already introduced into the country. The Jersey, because it is a small breed, may be at a relative advantage to large breeds when nutrition is the limiting factor and also because it may be better adapted to hotter regions. The Simmental was chosen because it will provide an alternative 'large' breed to the Friesian in terms of meat and milk with the possibility of using the male for draught purposes. The use of these three breeds will also provide a range of genotypes in respect of adaptation to the environmentally different conditions of the various parts of Ethiopia.

Preliminary results on the growth rate of different types of F_1 crossbreds have been published by Kebede and Galal (1982). The results, which appear in Table 4, indicate very little difference between Friesian and Simmental crosses, but the Jersey crosses were always significantly the lightest.

Studies on the efficiency of these crossbreds on different fattening rations have been also undertaken and the results have been published by Gebrewold *et al.* (1978) and O'Donovan *et al.* (1978). At present,

Table 4. Least squares estimates and their standard errors of different main effects on weight (kg) at birth, 90, 180, and 365 days of age.

	Birth weight			90 day weight			180 day weight			365 day weight		
	No.	Estimate	SE	No.	Estimate	SE	No.	Estimate	SE	No.	Estimate	SE
General mean	620	23.7	0.19	603	82.5	0.46	581	145.9	1.21	409	212.9	2.81
Sex:												
Female	316	-0.3a*	0.16	306	-1.2a	0.39	293	-3.0a	0.97	256	-8.0a	1.56
Male	304	0.3a	0.16	297	1.2b	0.39	288	3.0b	0.97	153	8.0b	1.56
Sire breed:												
Friesian	204	1.3a	0.25	197	5.5a	0.63	188	5.8a	1.37	135	7.7a	2.31
Jersey	216	-2.5b	0.24	210	-7.6b	0.59	203	-10.5b	1.36	145	-19.6b	2.27
Simmental	200	1.2a	0.25	196	2.1c	0.60	190	4.7a	1.37	129	11.9a	2.50
Dam breed:												
Barka	135	0.3a	0.35	132	2.7a	0.86	130	3.7a	1.99	83	20.8a	3.82
Boran	311	0.9a	0.22	298	1.3a	0.52	288	3.1a	1.22	210	-4.8c	2.18
Horro	174	-1.2b	0.29	173	-4.0b	0.80	163	-5.8b	1.87	116	-16.0b	3.24
Regression on age (kg/day)					0.82	0.056		0.18	0.144		0.18	0.202
Mean age days					91			181			364	

*Estimates followed by the same letter do not differ from each other ($P < 0.05$).

analysis is being undertaken to compare the growth rate of calves that have different levels of exotic blood. In addition, a preliminary analysis of the reproductive characteristics of the F_1 cows has been published by Azage *et al.* (1981) and Galal *et al.* (1981). Data collected on milk production is in the process of being analysed. Preliminary analysis of milk production has been undertaken and the results, as presented on Table 5, indicate Friesian and Simmental crossbreds to yield similar volumes of milk, i.e. 1854 kg and 1988 kg while the Jersey produces much less, i.e. 1585 kg in 305 days.

However, we are expecting the difference between the Jersey and the other two breeds to be much smaller when yield is related to metabolic body size, especially in the drier areas.

The Animal Resources Development Department (ARDD) of the Ministry of Agriculture is also undertaking a number of livestock development activities. One of its activities is the evaluation and improvement of some of the indigenous breeds and the distribution of improved animals to farmers. At present, it has three ranches and one AI center. The three ranches are the Abernosa Ranch, which has an area of 3000 ha and deals with Borana cattle; the Andasa Ranch with 200 ha of land and deals with Foggera cattle; and the Gobe Ranch with an area of 1800 ha and deals with the Arsi cattle type. Of these, the Borana improvement program has been going on for quite a long time and an elite nucleus of Borana cattle has been established. Results from unpublished data over the last 10-12 years from this ranch indicate live weight improvements in mean birth weight from 18-24 kg and weaning weight from 75-170 kg.

In addition to pure breeding, these ranches also undertake an extensive crossbreeding program whereby part of the herd is used for crossbreeding with the Friesian, and the F_1 heifers are used for distribution to farmers.

Under the Ministry of Agriculture, there also exists a development project known as the Arsi Rural Development Unit (ARDU), which was established initially independent of the Ministry of Agriculture, with the assistance of SIDA. It has a livestock research component and has contributed to breed evaluation work by studying the production potential of the Arsi breed. Results from the research carried between 1968 and 1974 as reported by Schoar *et al.* (1981) indicated that the Arsi type is a poor milk producer with a mean yield of 224 kg and that more than 50% of cows yield less than 100 kg in their first lactation (Table 6). The results also showed that yield can be increased seven fold by crossbreeding alone.

Table 5. Milk yields (kg) of F_1 cows from IAR cattle crossbreeding program.

	Total lactation	305 days lactation	305 days lactation: Holetta and Bako (wet areas)	305 days lactation: Adami Tulu & Melka Werer (dry areas)
Sire Breed				
Friesian	(103) 2312a*	(103) 1854a	(45) 2077a	(43) 2109a
SE	-83.7	-74.6	-71.2	-95.5
Simmental	(96) 2466a	(96) 1988a	(56) 2081a	(35) 2202a
SE	-92.0	-82.1	-63.2	-112.2
Jersey	(128) 2002b	(128) 1585b	(77) 1809b	(35) 1896b
SE	-84.3	-75.2	-63.8	-106.8
Dam Breed				
Barka	(58) 2353cd	(58) 1863cd	—	(48) 2118a
SE	-112.6	-100.4	—	-100.1
Boran	(175) 2371ac	(175) 1942dc	(98) 2080a	(65) 2020a
SE	-68.0	-60.6	-49.4	-49.4
Horro	(94) 2055bd	(94) 1622bd	(80) 1898b	—
SE	-104.6	-93.3	-61.8	—

*Estimates followed by the same letter do not differ from each other ($P < 0.05$).
No. of animals shown in parenthesis.

Table 6. Milk yield (kg) and lactation length (days) of purebred Arsi and first generation crossbreds.

	Lactation	No. of observations	Milk yield	Lactation length
Arsi	1	202	224	148
	2	65	417	227
	3	27	491	237
Arsi x Friesian	1	46	1 736	348
	2	13	2 034	343
Arsi x Jersey	1	16	1 397	351
	2	14	1 636	334

In addition to the assessment of the different indigenous breeds and their crosses for meat and milk production, their importance as draught animals has been also examined. As a 'spin-off' of the different crossbreeding programs, a joint program between the Institute of Agricultural Research, the International Livestock Center for Africa (ILCA), and the Ministry of Agriculture has been proposed with the objective of determining the relative efficiency of different types, and the level of crossbred oxen for traction. The assessment is being made in terms of work output, feed intake per unit of work output, time spent on various activities such as ploughing, cultivating etc., and the effect on yield. The traditional system, using the indigenous oxen is also included in the trial as control. The work is at present actively being carried by ILCA and valuable information is already being generated.

Breeding Goals and Policy

At present, there is no comprehensive livestock breeding policy in the country. The general policy that the Livestock Extension Program of the Ministry of Agriculture is following, is to give 50% heavy pregnant (last two month) Friesian crossbred heifers to small-scale farmers on a credit basis with freight, feed, and medication free until calving. In addition, 75-100% Friesian bulls are sold to farmers on a credit basis with freight, feed, and medication free for the first year. Farmers are advised to enclose grazing areas at the rate of 2 ha/animal for their improved animals, and concentrate feed is made available to them at cost, over and above the one that is given to them free of charge. Farmers are visited regularly by district development agents and regional animal husbandry experts. The source of crossbred heifers are the Abernosa and Gobe Ranches to which reference has been made above. At present, demand considerably exceeds the supply.

In addition to the small-scale dairy farms, there are a few large-scale dairy farms most of which are owned by the Ministry of State Farms. In these farms the general policy is to keep grade (75-pure bred) Friesian cows.

The importance of a carefully planned breeding policy for the country has been strongly felt by a National Technical Committee on Animal Breeding and Improvement, which has tried to determine a proposed policy for the country. The committee tried to review the different livestock production systems of the country; it proposed a recommendation of categorizing the breeding program according to the three broad agroclimatic zones of the country, namely, the lowlands, the mid-altitudes, and the highlands. The committee has tried to identify the type of farming followed in each of these zones, and the major constraints existing, before it established its final recommendations.

The recommended breeding policy as far as large ruminants is concerned can be summarized as follows:

1. In the lowlands, (where the major livestock production system is nomadic or semi-nomadic, there is very little crop farming, and the major constraint is scarcity of water and prevalence of disease), beef production using the indigenous breed should be intensified. The vast area of grazing lands untouched because of the lack of water can be turned into big beef ranches after the problem of water shortage is solved.

2. In the highlands where livestock production is integrated with crop production, land is scarce, and there is a feed shortage, (especially in the form of grazing land), an intensive type of dairy production system with the use of crossbred cows is recommended. Within the highlands, where management levels are of low standard and there is a problem of selling fluid milk, the use of 50% Jersey cross is recommended. In situations where the level of management is expected to be high, such as well organized cooperative farms and state-owned farms, the use of a higher level of crosses, up to 100% Friesians, is accepted. The male progeny from these dairy farms are also expected to be used as draught animals in the crop production system.

3. In the mid-altitudes, the type of farming practised is pastoralism with crop farming also playing a major role. The major constraints are disease problems and to some extent the lack of water. Once the major problems are solved and at the same time the marketing and transport systems are developed the committee felt that this area could be used as an important meat producing area. Also, it could act as a buffer zone between the lowlands and the highlands whereby culled dairy animals (old cows, bulls, infertile heifers) from the highlands, and excess animals from the nomadic zone, can be fattened by organized cooperatives or government feed-lots. In addition to beef production, in very few selected areas where nutritional stress is not very severe and where a market outlet for milk or its products is available, the use of 50% Friesian or Jersey crossbreds for milk production purposes is recommended.

This proposed breeding policy is expected to be incorporated in the 10 year Perspective Development Plan, which the Government of Ethiopia is at present actively preparing. In addition to the breeding policy, some of the proposed goals in this 10 year plan include the reduction of overall livestock numbers, an increase in production per head, the establishment of more dairy and fattening cooperatives, and the addition of more crossbred dairy heifer multiplication ranches.

Future Plans and Possible Collaboration with Australian Scientists

As previously mentioned the country has cattle of different genetic types and only very few of them have been studied. In addition to the programs included in the 10 Year Perspective Development Plan, it is felt that more investigational work on the indigenous types should be undertaken. The establishment and maintenance of a nucleus of elite herds from the different cattle types will be encouraged. Parallel with the work on the indigenous breeds, crossbreeding programs will also be conducted. The long-term cattle crossbreeding of the IAR will continue for another 3 or 4 years before final results are obtained.

Future emphasis will also be to look into different systems of managing dairy cows so as to increase fertility of cows, viability of calves, and increase output with minimum input etc.

Moreover, since livestock is an integral part of the whole agricultural production system in the country and is much inter-related with other productions such as crops and forestry, it is essential to define the main production complexes of a given area and determine an appropriate package that would increase the overall productivity of the area. Therefore, farming-systems oriented research is one of the future programs of the Institute of Agricultural Research.

Finally, with the big potential for livestock production in Ethiopia and with the very small amount of work conducted in livestock improvement so far, there is a lot more to be done in the future. The Government of Ethiopia has realized this and made provision for hiring international consultants to make a comprehensive study and evaluation of the livestock resources of the country. An Australian consulting firm, AACM, has been chosen to undertake this task. The firm has made a thorough assessment of the country's livestock resources, the potential for development, the major constraints facing the sector, and eventually proposed strategies for production, and identified potential projects. These projects, together with the government's plans, would allow ample opportunities to lay out co-operative programs between the Australian Government and the Ethiopian Government. This co-operative venture is further supported by the fact that the two countries have similar agroclimatic and topographic conditions. Also there is a rich experience and a large amount of accumulated research work by Australian scientists over a relatively longer period of time that could easily be adapted to Ethiopian conditions with very little modification.

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Meat Production Potential of Western Baggara Cattle in the Sudan

A.H. Osman*

THE Sudan is one of the largest African countries with an area of about 2.5 million km² and 18.5 million people. It is a predominantly agricultural country with a large development potential, especially in agriculture and livestock production. Its estimated agricultural land is more than 800 million ha although at present only about 7 million ha are under cultivation. Of the latter, only 1.6 million ha are under irrigation. The water resources, from the Nile and its tributaries as well as from rains that reach up to 1500 mm per annum in the southern part of the country, form a good basis for agricultural development.

Livestock numbers are estimated at about 18 million cattle, 30 million sheep and goats, and 2.6 million camels. Even though lamb and mutton are the meats of choice in Sudan, they represent only 20% of the total meat consumption; beef represents 70%, and meat of goats and camels is the remaining 10%.

According to origin and physical characteristics, the cattle of the Sudan can be classified into two main groups, namely Northern Sudan Shorthorn Zebu and Nilotic 'Sanga' cattle of southern Sudan. Western Baggara cattle belong to the first group. In terms of numbers and economic utilization, Western Baggara cattle are the most important cattle in the Sudan.

The name of the breed 'Baggara' means cattle herders in Arabic. This breed is found in western Sudan and is raised by nomadic tribes in Darfur and Kordofan provinces. Its homeland is the savannah belt of Central Sudan lying about latitudes 10°-16° N.

Physical Environment and Management of the Breed

Table 1 gives the main ecological zones of the Sudan. The savannah belt extends from about latitude 10°-16° N and represents about 40% of the total area of the country.

Western Baggara cattle are found in the savannah belt west of the Nile. The area is mainly a flat country with low vegetation of grass, herbs, and shrubs and in the northern part, a very few acacia trees. The grass cover, which is well developed immediately after the short-rainy season (July-September), soon dries up and suffers greatly from the hazards of fire. Further south, the savannah belt changes to woodland-grass savannah with trees that are predominantly broad leaved. The chief grasses are perennials.

Table 1. Major ecological zones of the Sudan.

Ecological zone	Total area (%)	Rainfall (mm)
Desert	29	0-75
Semi-desert	19.6	75-300
Savannah belt		
(a) low rainfall	27.5	300-800
(b) high rainfall	13.8	800-1 300
Flood region	9.8	800-1 000
Mountain vegetation	0.3	

Source: Harrison and Jackson — Vegetation Classification of the Sudan (1958). A technical report submitted to the Ministry of Agriculture, Khartoum.

Because of the scarcity of grass and water sources during the dry season in the north, and the insect infestation during the rainy season in the south, the pattern of animal husbandry is mainly nomadic. Baggara cattle are driven yearly more than 1000 km in a round trip (north-south) movement by nomadic tribes. However, more recently there is a trend towards partial settlement and pastoralism taking place around small villages. Some nomads are gradually turning into transhumant societies.

Under the prevailing conditions, Adams (1974) gave the age-sex structures (Table 2) of cattle in seven nomadic herds. It was found that the mean calving rate and interval were 59% and 710 days, respectively. The total offtake was estimated at about 3.7%.

Breed Characteristics

Breed Type

Baggara cattle are characterized by a relatively

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Table 2. Cattle herd structures in southern Darfur nomadic herd.

No. of permanent teeth	Age	Males	% of herd	Females	% of herd
4 pairs	Over 4 years	209	3.86	1 694	31.29
3 pairs	3.5 - 4 years	146	2.69	341	6.29
2 pairs	2.5 - 3.5 years	166	3.07	284	5.25
1 pair	2 - 2.5 years	239	4.41	282	5.25
	7 months - 2 years	455	8.40	547	10.10
	Under 7 months	471	8.77	580	10.62

large hump and short horns. Colours vary enormously though in this respect the herds of some tribes show a considerable uniformity. In Southern Darfur, some tribes show a preference for light-coloured cattle so that it is common to find herds in which the majority of the cattle are of white body colour. The hide is pigmented. In Kordofan there exist herds in which the general body colour is dark-red or brown-red.

Musculature is only moderate and tends to deteriorate from west to east. Baggara cattle in Kordofan are generally smaller than those in Darfur.

Reproduction and Milk Production

Gazal Gawazat is the only experimental station where Baggara cattle are bred and recorded. This station is situated in Sourthern Darfur at longitude 26° E and latitude 11° 40′N. Osman and Rizgalla (1968) ave described the development and management of the Gazal Gawazat herd. Table 3 gives reproduction and milk production traits of this herd as reported by Osman (1972).

Table 3. Reproduction and milk production of Baggara cattle in southern Darfur.

Trait	Unit	Records	Mean[a].
Age at first calving	month	125	66.7 ± 13
Calving interval	days	302	447 ± 8.6
Service period	days	237	153.3 ± 8.6
Gestation	days	295	287.2 ± 1.2
Services per conception[b].	—	291	1.25 ± 0.4
Daily milk yield	litres	374	3.58 ± 0.10
Lactation	days	374	232 ± 5.4

a. Least squares means; b. natural mating.

Body Weight and Growth Rate

Mukhtar (1961) studied birth and weaning weights of Baggara cattle on the Gazal Gawazat Experimental Station. It was reported that average birth weights were 24.5 and 21.8 kg, and average weaning weights 120.9 and 112.7 kg, for males and females, respectively.

Osman and Rizgalla (1968) studied normal growth and development up to one year of age of the same herd as well as the heritability estimates of some body weights and measurements (Tables 4, 5).

Table 4. Body weights and measurements of Baggara cattle.

Traits		Birth	210 day age	365 day age
Body weight, kg	M	23.4	116.1	151.3
	F	21.4	108.0	142.5
Heights at withers, cm	M	62.0	110.2	—
	F	59.9	108.3	—
Heart girth, cm	M	70.4	106.7	—
	F	67.4	102.4	—
Length from shoulder	M	41.0	71.5	—
to hook bone, cm	F	40.4	69.4	—
Pre-weaning average	M	—	0.44	—
daily gain, kg	F	—	0.41	—
Post-weaning average	M	—	—	0.23
daily gain, kg	F	—	—	0.22

Table 5. Heritability estimates of body weight and measurements of Baggara cattle.

Birth weight	0.49 ± 0.22
Height at withers (at birth)	0.24 ± 0.08
Heart girth (at birth)	0.29 ± 0.18
Length (at birth)	0.05 ± 0.11
210 d. weight	0.10 ± 0.14
Height at withers (at weaning)	0.20 ± 0.16
Heart girth (at weaning)	0.19 ± 0.16
Length (at weaning)	0.21 ± 0.16
365 day weight	0.26 ± 0.26
Pre-weaning av. daily gain	0.10 ± 0.14
Post-weaning av. daily gain	0.28 ± 0.20

When they are compared with other breeds of African cattle, it is evident that Western Baggara cattle attain more weight for age than most African Zebu breeds. The maximum birth, weaning, and yearling weights recorded for this breed in Gazal Gawazat Livestock Station were 36.3, 161.4, and 235.4 kg, respectively.

Feedlot Performance

El Shafie and McLeroy (1964) fed three age groups of Western Baggara intact male cattle, raised at the Gazal Gawazat Livestock Station, a ration composed of cottonseed hulls (26%), whole pressed cottonseed meal (20%), wheat bran (20%), Dura sorghum grain (20%), molasses (13%), and salt/mineral mix (1%). The feeding trial lasted for 100 days and the performance of cattle is shown in Table 6.

Table 6. Feedlot performance of Baggara cattle.

Average age, months	18	24	30
No. of animals	24	25	30
Av. initial weight, kg	128.8	169.7	236.4
Av. final weight, kg	229.8	282.6	353.9
Av. daily gain, kg	1.0	1.11	1.19
Feed conversion	6.5	7.12	7.75

Similarly Mukhtar and Mohammed (1969) fed 42 bull calves, ranging in age between 8-12 months, on three diets containing different levels of concentrates. The diets fed and the performance of these cattle are summarized in Table 7.

Table 7. Percentage composition of diets and feedlot performance of Baggara cattle.

Item	Diet 1	Diet 2	Diet 3
Dura (Sorghum) grain, %	66	33	—
Lucerne hay, %	33	66	99
Common salt, %	1	1	1
Av. daily gain, kg	1.09	1.31	0.74
Feed conversion	5.17	4.76	6.55

Meat Production

El Shafie and Osman (1971) slaughtered the cattle shown in Table 7 immediately after the feeding trial and the results are given in Table 8. El Shafie and McLeroy (1965) reported from very limited data an average dressing percentage of 53.7 for an older (18 months) group of Baggara cattle.

Table 8. Carcass characteristics of Bagarra cattle.

Carcass characteristics	Diet 1	Diet 2	Diet 3
Warm carcass weight, kg	87.0	84.8	68.7
Dressing percentage	50.2	48.1	46.4
Dissectable fat, %	10.9	8.6	5.2
Lean meat, %	66.3	66.8	68.0
Bone, %	22.7	24.2	25.8

Development Problems

Baggara cattle of western Sudan constitute the main source of meat for local consumption as well as for export. However, there are many ecological and socio-economic factors hindering maximum utilization of this valuable resource. These include shortage of water supplies during the dry season, communal grazing resulting in overgrazing and desert encroachment, poor genetic stock, and a lack of adequate infrastructure to facilitate marketing and thereby increase offtake rates.

So far arguments for and against nomadism as the only practical means to exploit the current ecological situation have been posed in several meetings and discussions. However, the consensus of opinion prevailing now in concerned circles is that there is an urgent need for study and research in the area of formulating new suitable production systems and development strategies and models for the Baggara of western Sudan.

Need for Collaborative Research Programs

The nature and complexity of the problems call for an integrated approach to research dealing with the development of the Baggara system of cattle production. Several agencies are now involved in or concerned about the development of Baggara. These include the Ministry of Agriculture and Irrigation, the Savannah Development Project, the Western Sudan Research Project and the Institute of Animal Production, University of Khartoum. There is need for an integrated plan of research and collaborative efforts to execute such a plan. The Institute of Animal Production, University of Khartoum has the largest group of animal scientists in the Sudan, and can therefore play an important role in research as well as coordination of the research programs.

The Institute of Animal Production has just concluded an agreement with FAO, Rome to carry out a pilot Kenana Selective Breeding Project in Central Sudan.

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The Indigenous Cattle Breeds of Nigeria: Problems and Potential

Saka Nuru and V. Buvanendran*

THE livestock industry, particularly beef cattle, plays an important role in the Nigerian economy. Beef cattle trade is the largest livestock enterprise in Nigerian agriculture. It involves millions of people engaged in various aspects of the enterprise, from trade in live animals and transportation to meat retailing. The livestock subsector, in which meat production is the most dominant aspect, is estimated to have accounted for at least 5% of the estimated N 36.07 billion (US $50.5 billion) GDP in 1980 while the subsequent contribution in the 1980s is expected to be much higher (Green Revolution Report 1981).

Nigeria has approximately 9.3 million cattle. The climate, which has a direct effect on the vegetation, fodder, and arable crops, and indirectly on the prevalence of tsetse fly, determines the distribution of the livestock breeds in the country. From the point of view of livestock production, five ecological zones need to be considered, as each presents its own climatic and management problems affecting breed distribution and survival.

In the extreme south, located between latitudes 6° and 7° N there is the forest zone with an annual rainfall of between 1800 mm and 3000 mm. At the other extreme is the Sahelian savannah zone in the north-east with an erratic annual rainfall of about 300-630 mm. Between these two extreme ecological zones, moving from the south to the north are the derived savannah zone, southern and northern Guinea savannah, Sudan savannah, and Sahel savannah. The bulk of the national livestock is in the Sudan zone. Generally, there is a bimodal rainy season in the southern part of the country but only one wet season in the north. Rains commence earlier in the south (April) and last longer (November). In the extreme northern parts, the rainfall is less than 500 mm and falls within 2-4 months, generally ending in late September or early October.

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Indigenous Cattle Breeds

Because of the wide ecological variations described above, cattle breeds are found in different ecological zones of the country in accordance with the climatic and vegetational characteristics. Nearly all breeds are dual purpose types. Although their milk potential is very limited, most breeds are kept primarily for milk production and meat is treated as a secondary product. Since the dense vegetation in the humid and subhumid southern zones harbours tsetse flies, which transmit trypanosomiasis, the only breeds that can exist in those areas are trypanotolerant breeds, namely the Keteku/Borgu and the Muturu/West African dwarf cattle.

Recently, emphasis on importation of Ndama from other ECOWAS (Economic Community of West African States) countries has been on the increase. Whereas the Muturu is found mostly in the forest and southern derived savannah, the Keteku, a breed originating from crosses of the Bunaji with the Muturu, occurs mostly in the Derived Savannah and Southern Guinea zones. It is intermediate in size between the two parents.

In general, the breeds of cattle can broadly be classified into 2 categories viz: the Zebu or humped breeds (*Bos indicus*) which are susceptible to trypanosomiasis, and the humpless trypanotolerant breeds (*Bos taurus*). The former constitutes about 88% of the total cattle population and are found in the Northern Guinea, Sudan, and Sahel Savannah zones in the northern part of the country. The following are the cattle types and estimated percentage of the total cattle population in the country:

Bunaji (White Fulani) 51%
Rahaji (Red Fulani) 14%
Sokoto Gudali 11.5%
Adamawa Gudali 11.5%
Others 12.0%

'Others' are represented mainly by Wadara cattle of the NE states and the *Bos taurus* types of the humid/forest zone.

Exotic beef breeds such as South Devon, Sahiwal, Santa Gertrudis, Droughtmaster, and Butana have been introduced for crossbreeding in government ranches and national institutions. Results of some crosses have not been encouraging.

Among the Nigerian breeds, the one on which most of the research has been carried out is the Bunaji, which is also more widely distributed within the 'Cattle Belt' or Northern Guinea Savannah.

Production Systems

Any discussion on the productive performance of cattle breeds in Nigeria will not be fully perceived if it does not first consider the production systems under which animals are kept. This is important because most reports on breed evaluation are based on data in institutional herds where the management and nutritional levels are very different to those that exist in the hands of pastoralists — the nation's custodians of nearly all the livestock.

The production system of the Fulani pastoralists range from one of complete transhumance through varying degrees of sedentarization to completely sedentary herd management. The herds owned by the highly mobile pastoralists are generally large, averaging about 50 head with a herd composition (Van Raay 1975) as follows: adult females 42%, adult males 10%, bulls 1-3 years 13%, heifers 1-3 years 16%, and calves 19%.

Their system of management can be regarded as one of rotational grazing on a large scale with animals migrating to the south during the dry season (when natural vegetation in the north is dry and scanty) and returning to the north during the early wet season when the danger from trypanosomiasis is greatest. On average, animals trek about 240 km during one transhumant cycle. From their temporary camps, which they establish in the north during the wet season, the Fulanis allow their cattle to graze crop residues from newly harvested fields at the beginning of the dry season. As the main dry season continues, and feed resources diminish, they move their herds on to the flood plains or graze along river banks (Fadamas) while at the height of the dry season, the herds are moved further south before returning north at the beginning of the rains.

Besides this group of mobile pastoralists, there are semi-nomads and the sedentary groups. The animals in the latter two groups, though trekking shorter distances and therefore subject to lesser stress, are generally not in as good a condition at the end of the dry season as the animals in the fully transhumant system. The latter animals are in better condition because they make optimum use of available vegetation both in the northern and southern regions of the country.

In the government or institutional herds, there is a high level of management especially with regard to parasite control, health, and nutrition. Often concentrates such as maize, guinea corn, groundnut, and cottonseed cakes are fed in addition to improved-pasture grazing, and conserved hay and silage. Under such a system, one expects a higher level of performance.

Productivity of the National Herds

Performance of Transhumant Herds

Production parameters of Bunaji cattle owned by Fulani pastoralists have been monitored by the International Livestock Centre for Africa (ILCA) as part of its livestock system research program in Nigeria (ILCA 1981). Their studies show that the average body weight of mature Bunaji female cattle in these herds is only 260 kg.

Calving percentage is low with a mean of 53%, which would imply a calving interval of 690 days. Weekly weight gain of calves from birth to 6 months is about 2.5 kg/week, and at 6 months the calves weigh between 55 and 60 kg. The weight gain is however dependent on the season of birth; those born during the wet season grow faster to 3 months because of the greater milk supply from their dams. The mean milk offtake of cows milking is 0.50 kg/head/day during the dry season, and 0.9 kg during the wet season resulting in a mean offtake per day of about 0.7 kg/day. The milk offtake over a whole lactation is thus only about 170 kg. Assuming about 250 kg of milk is consumed by the calf for 6 months, the total milk yield is only about 420 kg per lactation.

The low milk yield is chiefly due to the limitation imposed by a deficiency in the protein supply from dry savannah grasses in the dry season. Supplementation with about 1 kg of cotton seed cake has been shown to produce a marked increase in milk offtake during the dry season (Table 1). The increase in overall offtake is only marginal, but there is a dramatic increase in reproduction rates that have been reported to increase from 40-70% with supplementation. Thus, if the comparison is made on the basis of milk yield per cow from cows over 3 years old, a marked increase in milk yield can be observed. The main economic advantage from supplementation thus comes from an increase in fertility, and only marginally from the increase in milk yield.

Table 1. Milk off-take in unsupplemented and supplemented **Bunaji** Cattle kept under traditional system.

Season	Milk yield per day (kg)			
	Cows milking		Cows over 3 years	
	No Supplement	Supplemented	No Supplement	Supplemented
Dry	0.50	0.80	0.18	0.41
Rain	0.91	0.93	0.31	0.45
Whole	0.71	0.87	0.25	0.43

Source: Synge, B.A. 1980.

The annual offtake of cattle for beef from unsupplemented herds is about 8%. However, the increased fertility from supplementation shows that offtake could be much greater if nutrition were improved.

Performance in Institutional Herds

The performance of some of the indigenous breeds has been studied in many government ranches. Their weights at birth and at different ages are shown in Table 2. The weights at corresponding ages of crosses with exotic breeds are also presented for comparative purposes. These weights were obtained with natural grazing on savannah and improved pastures during the wet season, and hay or silage with supplementary feed during the dry season.

Among the northern breeds used for meat production, the Bunaji and Sokoto Gudali have been studied for their performance under feedlot conditions, for a period of 70-90 days. They received concentrates and roughage in the proportion of 2:1, the concentrates being constituted with cottonseed cake and maize in the proportion of 2:1. The weight gains and carcass qualities are shown in Table 3.

Table 3. Performance of Bunaji and Sokoto Gudali on feedlot.

	Breed	
	Bunaji	Sokoto Gudali
Initial weight	179	183
Final weight (kg)	265	273
Daily gain (kg)	0.99	0.90
Dressing percentage	52.5	50.3
Muscle (%)	69.4	68.4
Fat (%)	12.9	13.2
Bone (%)	17.8	18.4

Source: Olayiwole *et al.* (1979) and Buvanendran *et al.* (1983).

Table 2. Weights (kg) of indigenous Nigerian breeds and their exotic crosses in government ranches.

Breed	Location	Birth	Age (months)							Source
			3	6	12	18	24	36	48	
Bunaji	Shika	22.7	62.5	101.6	150.0	188.8	226.8	302.4	336.4	Wheat *et al.* 1972
Friesian x Bunaji	Shika	28.0	—	125.7	178.7	225.6	290.9	379.1	434.8	Umoh and Buvanendran (1980)
Bunaji	Kano	21.7	65.5	130.8	180.5	236.5	278.1	322.2	—	Wheat and
Bunaji	Kabomo	23.0	81.5	130.2	209.6	255.6	333.9	—	—	Broadhurst (1968)
Sokoto Gudali	Bulassa	22.4	62.6	97.2	126.7	165.9	208.2	278.4	—	Wheat and
Sokoto Gudali	Dogondaji	22.1	76.0	113.8	143.8	199.2	241.2	358.0	—	Broadhurst (1972)
Rahaji	Kano	23.4	81.5	126.2	162.5	217.2	254.5	344.7	—	Wheat (1972)
Wadara	Bornu	23.5	80.5	113.5	144.9	189.4	201.5	285.5	—	Wheat (1975)
Wadara	Dalori	24.4	60.7	79.3	111.0	135.2	160.9	201.6		
Wadara	Dalori	21.4	59.3	99.6	142.0	172.0	189.0	—	—	Nuru *et al.* (1981)
Wadara and Shorthorn	Dalori	25.5	79.5	120.2	150.0	—	—	—	—	

It is clear that these breeds have good potential for beef and it is the nutritional inadequacy that appears to prevent expression of this potential when raised on natural savannah grazing system.

In common with most Zebu breeds, the Bunaji has a rather late age at first calving of 40.4 months. That this is largely nutritional has been shown by a study where Bunaji heifers were placed on different levels of protein from 6 months of age. About 60% of animals on a 19% protein ration were pregnant at 24 months of age, while only 15% of those on an 8% protein ration were pregnant even at 34 months (Oyedipe *et al.* 1982a). Similarly, the calving interval of this breed based on over 300 observations was 439 days (Oyedipe *et al.* 1982b).

Season of calving has a significant effect on the subsequent calving interval; those calving during the dry season have a shorter calving interval (427 days) than those calving in the wet season (451 days). This effect is more pronounced for animals in the first parity, the mean calving interval for dry and wet season calves being 458 and 540 days, respectively. A possible explanation for this may be that animals require a minimum post-partum period before they commence cycling and it is the nutritional level at this time that determines conception. Thus, animals calving in the dry season may be ready at the onset of the wet season when conditions are favourable.

The Bunaji has an oestrous period lasting about 12.6 hours in the dry season (Voh *et al.* 1984). The oestrus activity is, however, more pronounced in the wet than during the dry season and conception rates are also significantly higher during the rainy than in the dry season (Zakari 1981). The pregnancy rates from field inseminations made in herds that received either supplementary concentrates or were not supplemented during either the wet or dry season are shown in Table 4 (Voh *et al.* 1983). Clearly, there is an advantage, in terms of pregnancy rates, of supplemented versus unsupplemented animals and inseminations done in the wet versus dry seasons.

Table 4. Pregnancy rates (%) of animals classified by management and season of breeding.

Season	Supplemented	Unsupplemented	Mean[a].
Wet	67.5	35.1	56.0
Dry	35.9	23.7	32.3
Mean[a].	59.3	32.8	50.4

a. Weighted means.

The milk yield of the Bunaji under moderately good nutrition (grazing on improved pasture during the wet season and conserved forage with minimum supplementation during the wet season) is about 1000 kg during a lactation of about 240 days duration. Crossing with the Friesian results in an increase in milk yield of about 60% in the F_1 and further increases in the ¾ and ⅞ Friesian (Table 5).

Table 5. Least squares means of milk yields, lactation length, and calving interval for Friesian-Bunaji grades.

Breed	Milk Yield (kg)	Lactation Length (days)	Calving Interval (days)
F_1	1 684	243.7	383.0
¾ Friesian	1 850	263.0	390.6
⅞ Friesian	2 051	286.1	393.0

Source: Buvanendran *et al.* (1981).

The performance of other Zebu breeds such as the Sokoto Gudali and Wadara are similar to that of the Bunaji in terms of body weight and reproduction. However, the Wadara is superior to the other breeds in milk production, producing about 1200 kg of milk per lactation (Nuru *et al.* 1983).

Among the trypanotolerant breeds, mature Muturu animals weigh only about 140 kg at 4 years of age. However, they are reported to have a good reproductive rate with an age at first calving of only 26 months and a calving interval of about 390 days.

The Keteku is a medium-size animal with a mean mature weight of 295 kg. These animals have a late age at first calving and long calving intervals, similar to the values observed for the Bunaji.

Though the trypanotolerant breeds are small in size, their productivity is not as low as what may seem from their size, if productivity is expressed as the weight of calf weaned per kg weight of the dam. Comparisons involving the Zebu and trypanotolerant breeds under different management systems (village and ranch conditions) have been made by ILCA (1979). Their studies show that trypanotolerant breeds, because of their superior reproductive performance and low cow mature weights are in most cases as productive as the Zebu.

Susceptibility of Breeds to Tropical Diseases

Other than the major epidemic diseases to which virtually all breeds are susceptible, the Zebu breeds are more prone to the common economic diseases such as trypanosomiasis and streptothricosis. The Nigerian *Bos taurus* breeds are known to be more resistant to these diseases, especially when the challenge is not severe and body condition is good. Thus the Muturu, Keteku, and Ndama breeds are more trypanotolerant and resist streptothricosis better than the Zebus and their crosses. Crossbred Zebus are more prone to mastitis, heart-water (*Cowdria ruminantium*), babesiosis, anaplasmosis, and other tick-borne diseases. To survive and maintain a reasonable productivity, both the pure exotic cattle and their crosses have to be adequately managed and routinely dipped against tick-borne diseases. Friesians and their crosses are also very prone to keratoconjunctivitis, especially just after the rainy season. With improved management, these diseases could be controlled.

National Breeding Policies

National breeding policies are formulated taking into consideration the following:

1. The production system, which as enumerated earlier, can be one of transhumance, semi-nomadic, settled pastoralist, or the commercial ranches.

2. The ecological zone, which can be classified as Derived Savannah, Guinea Savannah, Sudan-Sahel Savannah, and Montane.

3. The type of animal available in the different zones and the characteristics that they possess in relation to those areas.

Almost all the beef produced in Nigeria comes from indigenous animals raised by the pastoral Fulani. This system, where animals are kept on land of low potential while being exposed to the total impact of heat, parasites, periodic malnutrition, and shortage of water, is unlikely to change in the near future. Though the productivity of animals under the nomadic system is based on low input, it is a rational way of utilizing the available natural feed resources in the country. Therefore the breeding policy should be such as to breed animals suited to this system.

It is obvious that under the stressful conditions of the nomadic system, it is the indigenous animals that have the ability to survive. Exotic breeds or even their crosses with the local cows cannot survive in this environment. Small-scale studies by ILCA where Friesian crosses were distributed to nomadic herdsmen, have shown that the crossbreds succumb to trypanosomiasis and tick-borne diseases. Thus the basic breeding policy being recommended in the different ecological-zone production system combination is as shown below. Some of these are already being implemented.

Zone	*Production System*	*Breeding Policy*
Forest/Derived Savannah	1. Transhumant 2. Semi-settled/ commercial	1. Does not arise. 2. Beef with indigenous breeds, e.g. Muturu, Keteku.
Guinea Savannah	1. Transhumant	1. Beef and dairy with indigenous breeds e.g. Bunaji, Sokoto-Gudali.
	2. Semi-settled/ commercial	2. Dairying with Friesian crossbreds.
Sudan/Sahel Savannah	1., 2. Same as Guinea Savannah	1., 2. Same as Guinea, but Wadara is the indigenous breed preferred.

In support of this breeding policy, it is the intention of the government to set up breeding centres in the different agroclimatic zones for the breeds indigenous to each zone. A start has been made by the National Animal Production Research Institute (NAPRI) in establishing a centre for selective breeding of the Sokoto-Gudali. Livestock centres for Bunaji, Adamawa-Gudali, and Wadara are already in existence in some States, but a planned program of selection is not being carried out.

A scheme has also been formulated to performance-test bulls from farmers' herds in central stations. The basic idea is to institute a program of selection where possible. One possibility lies with nomadic cattle owners who are settled in grazing reserves. It is expected that each reserve will have a livestock service centre to provide assistance on animal health and feed (conservation methods etc.). The facilities in this centre can be utilized to performance test about 50-100 bulls at a time, which will be obtained from about 20 farmers. Each of them will later receive a tested bull.

Australian Assistance

An aspect of breed evaluation that has not been studied in Nigeria is that of the comparative resistance of different breeds to ecto- and endo-parasites. Tick infestations pose a problem to cattle productivity not only because of the harm that the ticks themselves cause but also because of the diseases they transmit — anaplasmosis, babesiosis, and heartwater. It has been demonstrated by Australian researchers that variation in resistance to ticks exists not only between breeds but also within breeds. It should be possible to exploit the latter variation and select for tick resistance to reduce the dependence on acaricides for tick control.

Assistance in training Nigerian scientists in the techniques used in selection for tick resistance should therefore be welcome. In this respect, it should be pointed out that in addition to *Boophilus* species, others such as *Amblyoma* and *Hyaloma* are also important under Nigerian conditions. Techniques suitable for the latter species are also required.

Training in this field will also be valuable in our dairy program, which is geared towards development of a breed incorporating Friesian and Bunaji blood. Friesian crosses have been observed to harbour more ticks and also to be more susceptible to anaplasmosis infection. Therefore selection for tick resistance should enhance productivity.

Possible Areas of Collaboration

Since nutrition plays such an important part in ruminant productivity, as clearly illustrated in this paper, more work will need to be done on pasture research and on the use of agricultural by-products. The importance of this research is not only in relation to improvement of productivity, but also to minimization of competition between human and ruminant populations for available grains in developing countries such as Nigeria.

Another important area worth consideration is breed evaluation using standard parameters and locations. So far, performance records of different breeds have been at varied locations with varied husbandry methods or management regimes.

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Productivity of Representative Breeds of Important Cattle Groups in Africa

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IN planning for increased cattle productivity in tropical Africa, a principal requirement is for information to predict accurately the usefulness of major breed types for different ecological zones, production systems, management levels, disease situations, and nutritional resources. My objectives are to indicate the main ecological zones of Africa, to give examples of the general types of cattle that can be maintained, and to assess the contributions of past research work in breed evaluation. Examples of breed characterization studies that highlight the value of such work, are reported for each of the three major indigenous cattle groups of Africa.

Cattle

Cattle in tropical Africa are used for several purposes, and in many cases cannot be separated into classes of beef, dairy, and work animals. The level of husbandry and management, and the attitudes of many owners toward their cattle, are such that productivity is often extremely low. Until changes are made in the traditional methods of husbandry, little or no increase in production seems likely through the introduction of potentially more productive breeds.

The indigenous breeds predominate and are classified in three very broad groups with further subdivisions possible: the humped Zebu; the small cervico-thoracic humped Sanga; and the humpless indigenous *Bos taurus* (e.g. Mason and Maule 1960; Epstein 1971). Existing indigenous cattle populations generally are well-adapted to survive and reproduce in their environment, because of qualities such as mothering and walking abilities, water economy, heat tolerance, disease tolerance, and ability to exist on low-quality feeds. Usually, however, they are late maturing, have poor growth rates and low milk yields, and produce small carcasses.

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Environmental Considerations

For the purposes of this paper, tropical Africa can be subdivided into five ecological zones: very arid (< 400 mm rainfall); arid to semi-arid (400-600 mm rainfall); semi-arid to humid, without tsetse (< 600 mm rainfall); temperate highland; and humid, tsetse-infested (Meyn 1978). These categories reflect elements of climate, elevation, and the occurrence of disease, and each is relatively uniform in terms of livestock production problems.

In the very arid zone (with 6% of the cattle), it is apparent that, in practice, little can be achieved through the introduction of new genotypes or by selection within indigenous populations.

In the temperate highland zone (with 22% of the cattle), it appears that the importation and use of other indigenous, crossbred, and exotic cattle types are completely feasible — based on their evaluation elsewhere. However, factors such as the production system, level of management, and feeding practices need to be considered.

In the humid, tsetse-infested zone with 6% of the cattle, the exploitation of trypanotolerant breeds of cattle offers one of the most important approaches to the control of the continental problem of animal African trypanosomiasis. Trypanotolerance can be reduced under certain adverse conditions, such as high levels of tsetse challenge, or it can be supplemented by previous exposure. Thus, to realize the full potential of trypanotolerant breeds, the main environmental factors that affect trypanotolerance should be identified and the extent of their influence quantified.

In the arid to semi-arid and semi-arid to humid zones (containing 66% of the cattle), the climatic, nutritive, and disease-parasite environment generally favours the cattle with varying percentages contributed by *Bos indicus* breeds because of their general adaptability. The most feasible approach here to synchronizing cattle genetic resources with other production resources is (1) to achieve the level of improvement in the natural environment that is favoured by economic factors, and (2) to use crossbreeding systems or composite breeds that exploit the cattle having most nearly 'ideal' optimum additive genetic composition contributed by both *Bos taurus* and *Bos indicus* breeds. A comprehensive program of characterization for the *Bos indicus* and *Bos taurus* cattle in these ecological zones is necessary to provide the basis for effective selection among breeds, for use in tropical crossbreeding systems, and/or as contributors to composite breeds.

Breed Characterization

Logical decisions on selection between breeds require that comparisons be made in the same environment, and information on a sufficient number of performance traits is available to construct an acceptable index of overall productivity. An assessment of past research work that satisfies these criteria can save on future inputs. A bibliography (Trail 1981) covering performance aspects of indigenous, exotic, and crossbred cattle in Africa south of the Sahara, lists approximately 500 references. These studies contain objective original data on some aspect(s) of reproductive performance, growth, viability, or milk production covering 30 years from 1949 to 1978.

An analysis of this bibliography indicates that only about 20% of the references contain information on three or more performance characteristics sufficient to allow characterization of breed types through a productivity index. For example, one simple productivity index used is 'weight of calf plus live weight equivalent of milk produced per unit weight of cow maintained per year' (this index is extended to cover more traits if information is available). In addition, only 20% of the references contain comparative information on two or more breed types. When analysis is made of these two necessary attributes combined, only 5% of the reports are shown to have sufficient data to allow breed comparisons on the basis of a productivity index. Thus, the majority of past research work does not provide really useful information about the comparative performance of cattle breeds in Africa.

Africander, Tswana, and Tuli Cattle of the Sanga Group

As recently as 10 years ago, there was almost no information on the comparative productivity of the indigenous Sanga breeds of cattle in southern Africa. Of the three locally available Sanga breeds in Botswana in 1970, about 80% were indigenous Tswana, 15% were Africander (mainly originating from South Africa imports), and a small proportion were Tuli. The Tuli breed had been developed since 1946 from Tswana types in the south-west of Zimbabwe. Mason and Maule (1960) suggested that the Africander differed substantially from the other native breeds of Africa. Although it was generally assumed to have descended from the cattle of the Hottentots, it has been developed by the Europeans into a true breed. In fact, the Africander can claim to be the first improved indigenous African breed because the breed society and the breed standard date from 1912.

In 1970, it was widely believed throughout southern Africa that the Tswana breed was an unimproved type, — hardy, but very slow growing with low milk yields. The Africander breed in contrast was believed to be a very superior indigenous breed and was used extensively for beef production as a pure breed and for crossing with other indigenous types. The use of Africander bulls on Tswana cows had been recommended for a number of years and encouraged through a government-operated bull subsidy scheme and by the provision of Africander semen at artificial insemination centres.

In 1970, when an animal production research unit was first established in Botswana, it was considered essential to compare these breeds under a standard of management that would be appropriate to the rapid development of the beef industry. Herds of Africander, Tswana, and Tuli cattle were assembled on a network of government ranches, with at least two breed types on each station. Management was standardized, involving fencing for animal control within a 3 month breeding season (January-March), weaning at 7 months of age, adequate provision of water, phosphate supplementation, and a preventive program against commonly occurring infectious diseases. Records were kept of all births, deaths, and monthly live weights (Animal Production Research Unit 1981).

Three major traits contribute to beef cattle production in Botswana, i.e. reproductive performance, viability, and growth; when combined, these three traits provide a productivity index to be calculated for breed comparison. Table 1 shows the productivity estimates of the three indigenous breeds expressed as 'weight of 18-month-old calf/cow/year'. These estimates involved several thousand animals in each breed group, over a 10-year period.

Table 1 indicates that the Tuli is the most pro-

Table 1. Productivity comparison of three indigenous breeds.

Breed	Calving (%)	Calf mortality (%)	18-mo wt (kg)	Wt of 18-mo-old calf/cow/yr (kg)	Index
Tuli	85	7	287	227	106
Tswana	79	8	295	213	100
Africander	67	12	277	163	76

Source: Buck *et al.* (1982).

ductive breed because of exceptional reproductive performance and low mortality, although its weight at 18 months was lower than that of the Tswana. The Tswana outperformed the Africander and was obviously a highly productive breed in its own right. Given a similar period of selection for productive traits, it would be expected that a Tswana breed could be formed that would perform equally as well as the Tuli. Under Botswana conditions, the Africander proved disappointing in all three production traits. By the late 1970s, it had thus become very apparent that there was no justification for the replacement of the Tswana by the Africander, and that inadequate knowledge of the production capabilities of the two breeds had resulted in the Africander being used too extensively.

If breed characterization information regarding the Africander and other Sanga breeds in southern Africa had been available earlier, it might have influenced decision making in several areas. In Botswana, more productive crossbreds might well have been utilized earlier, and Sanga types other than Africander might have been used in the development of breeds such as the Bonsmara in South Africa and Belmont Red in Australia. Thus productivity of these might well have been even higher.

Boran and Small East African Zebu Cattle of the Humped Zebu Group

A commercial beef cattle ranching scheme was begun in 1964 in western Uganda in an area that had been cleared of tsetse-fly by bush clearing and spraying with insecticides (Trail *et al.* 1971). A beef cattle research station was established and the aim of the breeding research carried out was to evaluate breeds for major economic traits for use in the ranching scheme. The breed characterization included dams of the Zebu and Boran breeds belonging to the humped Zebu group and the Ankole belonging to the Sanga group. The Zebu breed is frequently referred to as the Small East African Zebu and is indigenous to central and eastern Uganda and to specific areas of Kenya and Tanzania. The Boran breed is indigenous to northern Kenya and southern Ethiopia. It is recognized as the only improved indigenous breed in East Africa and it has been selected for beef production in the semi-arid higher elevation areas of Kenya since the 1920s. The Ankole breed is indigenous to the immediate area in Uganda and in adjacent areas of Burundi and Rwanda and is characterized by a wide span of horns.

The plan was to characterize the Ankole, Boran, and Zebu breeds as purebreds for maternal traits and in crosses with *Bos taurus* Angus and Red Poll males. Table 2 lists the results for the three indigenous breeds. The Boran, recognized as the only improved indigenous breed used for beef production in East Africa, was considered a standard of comparison or a control when this experiment was planned. The results show it to be superior to the Zebu and Ankole for all performance traits, with a cow productivity index (calf weight per cow exposed to breeding) 45% higher (Gregory *et al.* 1984).

Table 2. Indigenous purebred performance for individual and maternal traits.

	Boran	Zebu	Ankole
Calf crop born (%)	73	68	72
Pre-weaning viability (%)	92	85	81
Birth wt (kg)	29	23	28
9 mo-weaning wt (kg)	167	146	156
2-yr wt (kg)	286	247	272
Cow wt (kg)	329	259	335
Cow productivity index[a]. (kg)	99	67	69

a. Weight of 8-mo calf per cow per year.

In Kenya, analyses have been carried out between 1979 and 1983 of data on the Boran and its crosses with several different breeds under a range of management systems and ecological zones. These data were recorded in 11 commercial herds and Table 3 indicates the performance levels achieved over a 12 year period by pure Boran cattle under extensive range conditions with 720 mm annual rainfall (ILCA 1984). A mean calving interval of 13.8 months, preweaning viability of 94.6%, and 8 month

Table 3. Performance levels of pure Boran cattle in 11 commercial herds in Kenya.

Herd	Age at first calving (months)		Calving interval (months)		8 month weaning weight (kg)		Pre-weaning viability (%)		Calculated cow productivity index (kg)
	n	x̄	n	x̄	n	x̄	n	x̄	
1	94	40.1	263	12.4	302	166			159
2	164	35.0	541	13.0	610	174	710	87.3	140
3	3 386	38.2	12 634	13.3	3 876	200	12 634	94.8	171
4	180	38.2	455	13.3	163	148			128
5	438	36.8	1 426	13.5	883	176	922	95.1	149
6	137	34.4	540	13.5	137	187	594	99.9	166
7	1 143	42.6	3 423	13.7	2 396	191	3 338	97.1	162
8	887	55.9	2 293	14.7	2 221	162	2 410	91.8	121
9	418	35.9	1 007	13.8	508	156	924	98.2	133
10	817	41.8	1 610	17.2	1 886	120	2 198	92.3	77
11	157	40.1	498	13.5	292	170	585	94.0	142
Totals and means	7 821	39.7	24 690	13.8	13 274	174	24 315	94.6	141

calf weaning weight of 174 kg resulted in 141 kg of 8 month old weaner calf being produced per cow per year, or 35 kg of weaner calf per 100 kg of cow per year.

The results of these two trials confirm the superiority of the Boran over the small East African Zebu, and indicate the range of performance levels attainable by Boran cattle under commercial ranch conditions in East Africa.

N'dama and West African Shorthorn Cattle of the Indigenous Taurine Group

The exploitation of livestock possessing genetic resistance to disease is being given increasing consideration in livestock development programs, particularly where conventional disease control measures are too costly, too complex to implement or, as is also common, drugs and vaccines are not available. Such an approach is applicable to animal African trypanosomiasis, a disease that certain indigenous *Bos taurus* breeds of cattle are able to survive in tsetse fly endemic areas without the aid of treatment but to which other breeds rapidly succumb.

While trypanotolerant breeds are a well-recognized component in livestock production in certain areas of Africa, they represent only about 5% of the total cattle population in the 36 countries where tsetse occur (ILCA 1979). Failure to exploit these breeds can possibly be attributed to the belief that (1) their small size made them unproductive and (2) their tolerance to the local trypanosome population was a characteristic that had been acquired. However, it has now been confirmed that trypanotolerance is an innate characteristic and may, therefore, be genetically exploited (reviewed by Murray *et al.* 1982). Furthermore, in a recent survey of the status of trypanotolerant livestock in 18 countries in West and Central Africa (ILCA 1979), indices of productivity were examined using all the basic production data that could be found for each region, each management system, and for different levels of tsetse challenge (Table 4).

Table 4. Influence of breed on productivity.

Breed	No. of herds	Management	Tsetse challenge	Productivity index (kg)[a].
Zebu	20	Ranch	Zero-low	38.6
N'Dama/ WAS	30	Ranch	Low	37.1

Source: International Livestock Centre for Africa (ILCA), 1979.

a. Total weight of 1-yr-old calf and live weight equivalent of milk produced/100 kg of cow/yr.

The results indicated that in areas of no or low tsetse challenge the productivity of trypanotolerant cattle relative to other indigenous breeds was much higher than previously assumed. Comparative data between breeds were not available in many areas because the level of trypanosomiasis risk was such that breeds other than trypanotolerant ones could not survive.

With inputs from a number of donor agencies, ILCA is now coordinating a network of national research and epidemiological and productivity studies. The network will include nine countries in West and Central Africa: Zaire, Gabon, Nigeria, Ivory Coast, Congo, Benin, Togo, Senegal, and Gambia. The objective of these investigations is to evaluate the productivity of trypanotolerant breeds of domestic ruminants, and of other breeds where relevant, living under different levels of quantified tsetse-trypanosomiasis risk (Murray *et al.* 1983). First results were analysed in 1983 from sites in Gabon, Ivory Coast, Nigeria, and Zaire.

As a result of these findings, there is currently considerable interest in the use of trypanotolerant breeds in tsetse-infested areas of Africa. N'Dama heifers and bulls are being imported by several countries in West and Central Africa to form the nucleus of livestock development programs in tsetse infested areas (e.g. see African Development Fund preparation report, livestock development project, Republic of the Gambia, April 1982). During 1983 many thousands of N'Dama breeding heifers were imported by sea and air from Gambia and Senegal to Gabon and Nigeria.

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Part 2

Australian Work: Current Activities
and
Possible Contribution

Tropics, Subtropics and Temperate

Results and Implications of Studies Involving Brahman Cattle in South Australia

M.P.B. Deland*

THE major land area (90%) of South Australia is arid or semi-arid, with annual rainfall less than 400 mm and approximately 15% of the cattle population (current total approximately 700 000). Approximately 50% of the cattle population is found in a small area (3%) in the south-east of the state where the rainfall is greater (up to 700 mm).

Steers of predominantly Shorthorn, Hereford, or Angus breeding, which had been reared in semi-arid areas, traditionally were transported to higher rainfall areas to fatten and slaughter. Heifers and cows surplus to breeding requirements in the arid areas were also brought south for breeding.

Prior to the mid 1960s no attention had been given to objective evaluation of the performance of beef cattle in the State, other than animal health issues, which were important because of the long distances stock were transported. Cattle in this State are relatively free of diseases and parasites when compared with cattle from tropical environments, e.g. no cattle tick.

The first research centre to concentrate on cattle work was established in the south-east at Struan near Naracoorte in the late 1960s and early 1970s. In the area serviced by this Centre, rain falls throughout the cooler months (April-November) and there is a marked summer drought in which maximum daily temperatures can exceed 40°C. The rainfall (mean 574 mm), which is reliable when compared with other areas of the State, supports the growth of improved perennial pastures. These provide grazing for dairy cattle in the southern area, and for sheep and beef cattle breeding and fattening throughout the region.

Most calves produced in the area are sold for slaughter before 12 months of age, but some producers prefer selling stock at 15-18 months, which usually corresponds with high winter prices. Cows used for breeding purposes are principally of British beef breed origin (Hereford and Shorthorn) but dairy and dairy x beef breed crosses have become important in recent years since supplies of Shorthorn dams from northern Australia have become unreliable. Growth rates of calves are high (Deland *et al.* 1974; Deland and Saunders 1976) relative to other areas of Australia (Morgan and Saul 1981; Barlow and O'Neill 1978) and producers have tried to improve production by genetic means. In the 1960s, local producers became interested in increasing size and growth rate by using large European breed and *Bos indicus* bulls. Trials were conducted to provide reliable information on production and carcass characteristics of the progeny of these sires and the commonly used dams in the south-east of South Australia. Calving difficulties were also assessed. This was further developed to include studies of crossbred cows in both semi-arid and mediterranean environments, and production per hectare studies were initiated using some of the most promising combinations. This paper concentrates on the trial work involving Brahman and Sahiwal crosses.

Beef Production from Crossbred Calves at Struan Research Centre

Hereford, Charolais, and Brahman sires were mated to Hereford, Shorthorn, Jersey, and Friesian x Shorthorn cows for four successive years from June 1969 and the results reported by Deland *et al.* (1983). Cows in difficulty at calving were assisted and the degree and nature of the difficulty were noted (Table 1).

Charolais sired calves were given most assistance and Hereford sired calves the least. There were no significant differences among sire or dam breeds in calf mortality. Cows and calves were weighed every 2 months. Calves were grazed with their dams until approximately 270 days old, after which they grazed separately at pasture. At a mean age of 370 days, calves were given access to hay and oats *ad libitum* after a 14-day build up period. The weights of calves at various ages are given in Table 2.

Charolais sired calves were heavier than Brahman and Hereford sired calves at all ages, although the

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Table 1. Percentage of calves assisted at birth and of calves that died within 24 hours of birth for each sire and dam breed.

Breed	Assisted %	Died %
Sire		
Hereford	2.1a*	5.4
Charolais	15.9b	7.9
Brahman	6.8c	7.4
Dam		
Hereford	10.9ab	6.5
Shorthorn	5.0a	5.6
Jersey	4.3a	5.3
Friesian x Shorthorn	13.8b	10.4

*Values not followed by a common letter differ significantly ($p < 0.05$).

Table 2. Birth weight (BW), weights at 270 (W 270), 370 (W 370) and 430 (W 430) days old (all weights in kg).

Attribute	BW	W 270	W 370	W 430
Sire breed				
Hereford	31.5	238.8	303.8	326.3
Charolais	35.6	259.2	344.7	372.1
Brahman	34.5	227.2	319.7	351.4

difference between birth weights of Brahman and Charolais sired calves was not significant. Brahman sired calves were significantly heavier than Hereford sired calves at birth, significantly lighter at 270 days, but heavier at 430 days. The greater calving assistance given to Charolais and Brahman sired calves when compared with Hereford sired calves was most probably due to the higher birth weight of these calves. The higher weight of Charolais, compared with Brahman and Hereford sired calves at weaning is consistent with results of Deland *et al.* (1974); Smith *et al.* (1976); and Morgan and Saul (1981).

The lower weaning weight of Brahman sired calves when compared with Hereford sired calves is different from results of Barlow and O'Neill (1978). It is likely that the lower growth rate of Brahman crosses compared with Hereford sired calves was due to low winter temperatures that prevail during the pre-weaning growth period at Struan, as post-weaning weights (corresponding to summer growth) of Brahman crosses exceeded those of Hereford sires at Struan. Steers were slaughtered at a commercial meatworks and carcass measures taken. Carcass weight and fat thickness of calves slaughtered at approximately 15 months of age are given in Table 3.

Table 3. Mean carcass weight (kg) and fat thickness (mm) of carcasses from 15 month old progeny by Hereford, Charolais, and Brahman sires.

Sire Breed	Carcass weight	Fat thickness
Hereford	167.4a*	4.6a
Charolais	195.1b	1.2b
Brahman	180.2c	3.6a

*Means not followed by a common letter differ significantly($P < 0.05$).

Charolais sired calves had heavier carcass weights than Brahman sired calves, which were significantly heavier than Hereford sired calves.

Similar trends for growth and carcass traits of Brahman and Hereford sired calves were noted in two other trials reported by Deland *et al.* (1974) and Deland (1979).

Calf Production from F1 Cows of Half Hereford Breeding

The reproductive and calf-rearing performance of a range of crossbred females was studied in three South Australian environments. Three groups of crossbred heifers born in the years 1972, 1974, or 1975 from base cows of Hereford, Friesian, Shorthorn or Jersey breeding were obtained either from Struan Research Centre or by outside purchase. In 1972, Hereford-crosses with Sahiwal, Brahman, Shorthorn, Jersey, or Charolais, were obtained and in 1974 and 1975, Hereford x Friesian and Simmental x Hereford-crosses, also were obtained. The choice of breeds aimed to include the basic types of cattle that are likely to be present in Australia, i.e. large and small dairy types, British beef breeds, *Bos indicus* dairy and beef types, and European beef and beef-milk types. The 1972 and 1975 born heifers remained in the lower south-east of South Australia at Wandilo (765 mm annual rainfall) and Struan (574 mm), and have been studied for 7 years of production. The females born in 1974 have been recorded for 8 years in the Murray Mallee at Wanbi, a marginal cereal area with 320 mm annual rainfall.

Approximately 20 heifers per breed-cross were allocated to each location (Table 6). Heifers were either bred on Struan Research Centre or purchased from private properties at 7-8 months of age. They were selected on the basis of birth date and were sired by several bulls (range 4 to 10). Each crossbred group was represented by animals from several donor herds (range 2 to 4). Heifers were first joined to bulls at a mean age of 15 months. Mating commenced in the first week of June each year and continued for 9 weeks.

In general, Friesian-, Shorthorn-, and Jersey-cross heifers attained puberty earlier than Brahman- and Sahiwal-crosses with Charolais-and Simmental-crosses being intermediate. At Struan in 1976, a year of poor feed conditions, onset of oestrus was delayed and most heifers, particularly the Brahman-, Sahiwal-, and Simmental-crosses, did not attain puberty until the following summer. This appears to have affected the production ranking of calves born in 1975 for the whole of their lives.

Differences in fertility, and consequently weaning percentage, were most pronounced in the first year (Table 4). Breed differences in maternal behaviour at first calving were studied in 1974 and have been reported by Johnsson *et al.* (1980).

Table 4. Percentage of calves weaned from Hereford crossbred cows for the several years at each of three locations.

Sire of Cow	1974	75	76	77	78	79	80	81	82	83
					Wandilo					
Jersey	85	90	95	100	84	68	84			
Charolais	58	88	100	96	87	78	90			
Sahiwal	50	87	90	100	88	75	81			
Brahman	21	94	89	89	94	69	73			
Shorthorn	55	85	100	82	75	100	87			
					Wanbi					
Friesian			100	95	65	75	89	76	76	93
Simmental			76	82	71	88	88	75	67	82
Jersey			88	95	65	75	95	100	90	88
Charolais			76	94	65	82	88	94	67	77
Sahiwal			64	73	82	91	91	100	100	110
Brahman			43	76	76	77	111	100	89	81
Shorthorn			55	75	80	75	79	67	63	67
					Struan					
Friesian				56	48	68	86	90	95	85
Simmental				0	78	72	75	77	100	65
Jersey				32	76	70	84	95	84	83
Charolais				14	65	55	74	88	88	82
Sahiwal				3	97	80	79	100	100	85
Brahman				5	68	68	83	81	92	85
Shorthorn				46	67	92	87	92	100	86

Calves reared at Wandilo and Struan were weaned at approximately 9 months of age while those reared in the Murray Mallee were weaned at 6-8 months of age depending on pasture availability each year. At each location in each year, Shorthorn-cross dams weaned calves that were among the lightest, whereas Friesian-, Simmental-, and Jersey-crosses weaned calves that were among the heaviest (Table 5).

Table 5. Mean weaning weight (kg) of calves of Hereford crossbred cows for the several years at each of three locations.

Sire of cow	1974	75	76	77	78	79	80	81	82	83
					Wandilo					
Jersey	262	286	307	296	260	301	304			
Charolais	259	281	314	305	259	315	321			
Sahiwal	245	277	274	277	249	286	284			
Brahman	233	274	272	286	250	292	285			
Shorthorn	235	250	271	288	240	283	274			
					Wanbi					
Friesian			195	181	181	290	292	252	221	293
Simmental			191	179	191	281	303	253	239	304
Jersey			193	177	177	266	209	237	199	269
Charolais			179	172	178	278	236	248	226	287
Sahiwal			194	177	177	282	236	209	227	246
Brahman			175	179	183	264	250	233	203	261
Shorthorn			153	151	124	248	257	215	209	263
					Struan					
Friesian				236	246	273	262	312	258	305
Simmental					242	279	283	330	268	315
Jersey				226	242	261	258	303	269	297
Charolais				197	218	261	263	318	265	297
Sahiwal				154	233	262	244	301	256	275
Brahman				243	248	262	271	279	273	282
Shorthorn				189	212	243	249	286	245	281

Jersey crosses had a high calving percentage and weaned heavier calves in the first 2 years than Charolais-crosses at Wandilo, while in succeeding years, Charolais-cross productivity exceeded that of the Jersey-crosses, but not significantly so. Sahiwal-crosses had low fertility as heifers at Wanbi and Struan, but exhibited high productivity thereafter.

Carcass weights (Table 6) followed closely the trends noted for weaning weights with Shorthorn-crosses producing significantly less than the other crosses. Overall, Jersey-and Sahiwal-cross carcasses tended to be fatter (Table 7) and Charolais-and Shorthorn-cross carcasses leaner than the carcasses of the other crosses, although these results varied between locations and years. In 3 years, carcasses were individually valued by public carcass auction. Relative values followed carcass weight closely and there was no apparent discrimination against any particular cross in terms of price per kg of carcass weight.

Table 6. Carcass weight (kg) of steer calves from Hereford crossbred cows for the several years at each of three locations.

Sire of cow	1975	76	77	78	79	80	81	82	83
Wandilo									
Jersey	164	183	221	150	193	168			
Charolais	172	187	239	158	189	179			
Sahiwal	164	164	174	145	181	179			
Brahman	164	148	226	142	173	155			
Shorthorn	141	140	221	136	172	153			
Wanbi									
Friesian		162	113	221	188	188	165	128	177
Simmental		153	120	231	193	211	173	141	180
Jersey		151	110	208	177	179	160	121	156
Charolais		153	114	239	180	199	158	139	174
Sahiwal		162	115	226	181	174	161	126	149
Brahman		148	109	219	179	170	150	120	150
Shorthorn		126	95	201	166	172	151	120	146
Struan									
Friesian			143	146	147	164	168	155	195
Simmental			—	138	157	175	181	160	195
Jersey			134	134	133	157	161	168	165
Charolais			—	122	141	151	166	161	175
Sahiwal			—	131	148	149	162	156	160
Brahman			152	140	155	162	158	166	169
Shorthorn			103	118	119	146	147	141	171

Cows were culled if they failed to calve in 2 consecutive years, or if they developed terminal diseases, such as eye cancer. Total weaned weight of calf per cow at commencement of the trial was used to assess the combined effects of fertility, cow survival rate, and the ability to wean calves (Table 8).

There was no evidence of a greater failure rate of dairy-cross cows relative to other crosses up to 8 years of age (Table 8).

Heifer fertility is a major consideration in overall productivity. Thus, if crossbred heifers are purchased without selection before first mating, the dairy types (Friesian and Jersey-Hereford) are likely to give higher productivity. However, if purchased in-calf, or later as producing cows, the differences between crosses in subsequent productivity are likely to favour the later maturing crosses.

Table 7. Fat thickness (mm) of carcasses of steer calves from Hereford crossbred cows for the several years at each of three locations.

Sire of Cow	1975	76	77	78	79	80	81	82	83
Wandilo									
Jersey	4.2	10.0	5.5	6.0	13.8	12.0			
Charolais	2.1	7.8	5.2	2.2	8.8	8.9			
Sahiwal	3.8	9.3	6.0	4.3	9.7	12.0			
Brahman	3.0	8.0	5.7	2.9	9.1	9.9			
Shorthorn	2.5	5.7	4.8	2.8	9.0	7.6			
Wanbi									
Friesian		1.4	2.5	7.2	10.1	10.7	5.0	3.3	5.6
Simmental		3.5	2.9	7.7	10.6	10.1	4.9	2.8	2.4
Jersey		1.7	2.6	8.4	9.9	13.6	8.5	3.9	6.9
Charolais		0.6	1.8	5.1	6.8	9.0	3.6	3.0	1.6
Sahiwal		1.1	1.8	6.8	8.1	9.2	6.3	3.5	5.1
Brahman		1.5	2.1	6.7	10.3	10.3	5.0	3.3	4.3
Shorthorn		3.8	2.1	4.9	6.5	8.1	7.5	3.7	3.5
Struan									
Friesian			3.7	5.4	5.8	6.4	6.7	5.0	9.0
Simmental			—	4.2	8.2	7.2	7.4	3.8	7.1
Jersey			4.5	5.3	6.2	8.6	9.7	7.7	10.1
Charolais			—	2.4	5.8	6.1	5.7	4.6	5.2
Sahiwal			—	4.5	6.9	7.3	8.0	4.4	6.3
Brahman			6.0	5.6	7.5	9.1	6.2	6.1	6.7
Shorthorn			2.6	5.6	7.0	7.0	6.3	5.2	7.7

General Comments

A wide selection of breed types was used initially, to cover those breeds already used by beef cattle breeders in the State and to allow for the possibility that calves surplus to the dairy industry in the State of Victoria may become available for beef production. The Department of Agriculture has a relatively small number of staff working on beef cattle, and recording is confined to those characters known to have significant value in either management or economic terms.

For the first few years, all calves were eartagged, then weighed and measured (length, height, head width, head length) within 24 hours of birth. No correlation was found between the measurements and any economically related factor other than birth weight, so linear measurements were discontinued. Blood cortisol levels were determined during artificial insemination of cows and at 7-weekly intervals from heifers prior to their first calving. A significant

Table 8. Number of Hereford-cross heifers entering trial, number remaining, and total weaned weight (kg) of calf per cow commencing the trial at each of three locations.

Breed cross	Wandilo No. heifers at start	Wandilo No. cows remaining August 1980	Wandilo Total weaned weight of calf per cow 1980	Wanbi No. heifers at start	Wanbi No. cows remaining August 1983	Wanbi Total weaned weight of calf per cow 1983	Struan No. heifers at start	Struan No. cows remaining August 1983	Struan Total weaned weight of calf per cow 1983
Friesian				20	15	1 415	23	19	1 329
Simmental				18	11	1 366	19	14	1 252
Jersey	20	17	1 683	20	16	1 395	22	18	1 259
Charolais	24	19	1 756	18	13	1 386	21	16	1 199
Sahiwal	25	11	1 216	11	10	1 529	30	26	1 395
Brahman	19	13	1 136	21	16	1 229	20	13	1 074
Shorthorn	20	13	1 308	20	12	998	24	22	1 364

correlation was found between blood cortisol level and subsequent calving percentage of crossbred heifers (Obst and Deland 1977) but this relationship was not significant within breeds due to very high standard deviations. Shin dissections were carried out to determine percentage of meat, fat, and bone in carcasses.

Characters now measured include cow and calf weights every 7 weeks, calf weight and fat score at weaning, and carcass weight and fat thickness of all sale animals. This requires that calves and cull cows are individually traced through the meatworks. Additional information such as fat colour, excessive carcass damage, disease (particularly eye cancer), teeth loss, and foot problems are recorded.

The information gathered is used in different ways by different sections of the industry, e.g. facilities and expertise have been used to facilitate insemination programs where Sahiwal semen was used on private dairy herds to produce calves for exports to Asia. Different crossbreds have been used in private herds to achieve higher financial returns than previously. Livestock buyers and meatworks management have been provided with the opportunity to follow cattle of known age and breeding through their meatworks to improve their buying operations. Some cattle producers have been given the opportunity to export either live cattle or beef to Asia, whereas in the past they were rearing cattle not sought by those markets. The Korean market has provided an outlet for cattle that produce carcasses with less fat and more muscle than our traditional types.

It is not possible to extrapolate the production data directly to tropical environments as many of the diseases and stresses would be quite different to those in South Australia. However, where disease and stresses are controlled the results could be used to provide useful reference points for production levels.

The maintenance of high productivity of crossbred cows with dairy breeds in their parentage under adverse climatic conditions at Wanbi raises the possibility that semen of dairy breeds could be used on indigenous cattle to produce cows with relatively high productivity under adverse local conditions.

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Breed Evaluation of Large Ruminants in Southern Australia

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THE most common breeds used for beef production in southern Australia are Hereford, Angus, and Beef Shorthorn, which are all of British origin. In recent years, other breeds such as the Charolais, Simmental, and the Zebu (Brahman) have been introduced, and there has been an increase in the use of dairy cattle (Friesian and Jersey breeds).

Crossbreeding systems in many countries produce more beef than straight breeding systems because of the benefits of heterosis, particularly in the breeding female. Research work on beef cattle at the Pastoral Research Institute, Hamilton, in the Western District of Victoria over the past 15 years has provided objective information on the productive characteristics of the major breed types available, and of their crosses when used for beef production in the pastoral environment of southern Australia.

Environment

Meteorological records at Hamilton indicate a mean annual rainfall of 700 mm with a winter incidence. July is the wettest (94 mm) and coldest month with mean minimum and maximum temperatures of 1.9° and 7.6°C. January and February are the driest (about 30 mm/mth) and hottest months (ambient temp. min. 11° and max. 26°C). Mean daily wind speeds vary only slightly on a monthly basis from 10.9-13.4 kph throughout the year.

Pasture growth from natural rainfall can usually be maintained from April-December each year. Growth rates of 15-20 kg DM/ha/d are achieved from April through to the end of August after which pasture growth rate increases rapidly to a peak of about 70 kg DM/ha/day in December. From January to March, there is little growth (< 5 kg DM/ha/d) and pasture is normally dry. Irrigation is rare in the Western District due to a lack of underground water and poor water storage facilities.

The main pasture components are perennial ryegrass, phalaris, cocksfoot, annual grass species, subterranean clover, strawberry clover, and white clover. Soils are generally deficient in phosphorus and annual applications of about 10 kg P/ha are maintained. Potash is also applied to maintain soil potassium levels.

A proportion of spring pasture growth is conserved as hay for feeding back to cattle in the winter months when pasture growth is limited due to waterlogging and cold ambient temperatures, and when lactation cows are being mated. Cattle can be maintained on wheat supplements fed at pasture during drought.

Mating is recommended to start on June 1 to allow calving in March-April when the pasture starts its new season growth, allowing weaning to occur in December or when the pastures are drying-off from lack of soil moisture.

Control of round worms in cattle is achieved by drenching weaners, first calf heifers, and second calf cows together with bulls during December-January (summer drench) and March-April (autumn drench) with a third drench in July (winter-early spring). There is no benefit from routine louse treatments. Acute liver fluke and black disease are rarely found. Chronic fluke disease is seen mainly in cattle under 2 years old. Cattle grazing fluke-prone areas should be vaccinated against black disease.

Cattle are extensively managed on fenced pasture; stocking rates possible are 1.0-1.5 breeding cows/ha. They are not shedded at any time of the year.

Techniques for Evaluation of Different Genotypes

Genotypes may be grazed together for measurement of aspects that determine per head productivity (not efficiency), e.g. in steers growth is measured by regular weighings, and carcass measures at slaughter, which can be either simple (e.g. carcass weight and fat depth) or detailed (e.g. proportions of bone, muscle and fat). A distinction needs to be made

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between the evaluation of genotypes as sires versus their evaluation as dams, e.g. Brahman sires mated to Hereford cows result in a high incidence of dystocia whilst Brahman or Brahman cross cows have a relatively low incidence of calving difficulty. In heifers and cows, growth is measured by regular weighings, and oestrus by means of vasectomized bulls fitted with chinball harnesses and/or heat mount detectors; measures of fertility are age at first oestrus, post-partum anoestrous interval, conception rate during the early part of the mating period, final pregnancy rate; ease of calving is measured by the degree of assistance provided and calf mortality; calf growth, milk consumption, and weaning weight are also recorded. Some attempt could be made to measure feed intake at pasture but this has not yet been done at Hamilton.

Genotypes may be grazed in separate paddocks to allow for the effects of genotype differences in feed intake and to provide evaluations in production per ha. This requires paddock replication and preferably a range in stocking rate (e.g. at Hamilton three stocking rates, 1.0, 1.4, and 1.8 with two replicates). In cows, emphasis is placed on measures of fertility especially under conditions of feed shortage such as at the high stocking rate.

Genotypes Evaluated at Hamilton

Hereford and Friesian cows were grazed together and artificially inseminated with Hereford (including Poll Hereford), Friesian, Charolais, and Brahman semen. With the exception of Charolais semen from Britain and New Zealand, only semen from Australian bulls was used. The number of sires used varied from 13 for Brahmans up to 35 for Friesians.

Genotypes:	Sire		Dam
	Hereford	x	Hereford (HH)
	Friesian	x	Hereford (FH)
	Charolais	x	Hereford (CH)
	Brahman	x	Hereford (BH)
	Hereford	x	Friesian (HF)
	Friesian	x	Friesian (FF)
	Charolais	x	Friesian (CF)
	Brahman	x	Friesian (BF)

The effects of breed of dam, breed of sire, heterosis, and sex on gestation length, calving difficulty, birth weight, calf mortality, milk production, and weaning weight were measured. The female progeny were assessed for age at puberty and calving difficulty when mated to Simmental sires. Carcass assessment of the steer weaners was also completed.

Production/Head

The experimental results summarized in this section are those reported by Morgan, Clark, Saul, and Spiker as referenced in the tables.

Birth Traits

Data for gestation length, birth weights, and calving difficulty are presented in Table 1.

Table 1. Least square means for birth traits (Morgan and Saul 1981).

Breed group	Gestation length (days)	Birth weight (kg) Male	Birth weight (kg) Female	Calving difficulty score Male	Calving difficulty score Female
Dam breed:					
Hereford	287.1	34.1		1.85	1.31
Friesian	285.5	38.1		1.33	1.18
Sire breed:					
Hereford	283.5	35.3	32.7	1.27	
Friesian	282.4	36.3	33.5	1.40	
Charolais	287.8	39.5	37.9	1.53	
Brahman	291.4	39.3	34.7	1.47	

Gestation lengths of calves sired by Brahman bulls were the longest (291 days) compared with Hereford and Friesian sired calves of about 283 days.

Birth weights: Calves born to Friesian dams weighed 3.9 kg more at birth than calves from Hereford dams. Brahman sired calves demonstrated a larger sex difference in birth weight than other breeds. The effects of sire breed on calf birth weight interacted with the effects of cow age/year and calf sex.

Calving difficulty: Overall a higher proportion of Hereford than Friesian cows were assisted at calving (13.7 vs 7.9%, $P<0.05$). Hereford-sired calves were assisted less often than Charolais-and Brahman-sired calves (6.5 vs 13.5 and 12.4%, $P<0.05$) with Friesian-sired calves being intermediate (10.6%).

There was a significant interaction between the effects of dam breed and sex on calving difficulty score. The score was higher for Hereford cows giving birth to male calves than for Hereford cows giving birth to female calves for which the score was similar to that for Friesian cows giving birth to either male or female calves. Hereford cows had higher calving difficulty than Friesian cows as 2 and 3 year-olds but not as 4 and 5 year-olds.

Calf mortality: Mortality at birth and up to 3 days of age was higher in male than in female calves (10.5 vs 5.2%, P<0.01). Male calves sired by Hereford and Friesian bulls had a lower mortality than male calves sired by Charolais and Brahman bulls (5.9 and 4.3 vs 14.3 and 15.7%, P <0.05). Female calves sired by Brahman bulls tended to have a higher mortality than those sired by Hereford, Friesian, and Charolais bulls (8.5 vs 3.4, 4.3 and 4.4%). Calf mortality decreased with increased age of cow from 2, 3, 4 and 5 year-olds (13.5 vs 7.8, 5.7 and 5.4%, respectively, P<0.05).

Calf Weaning Weights

Calves born to Friesian cows were, on average, 29% heavier at weaning than calves born to Hereford cows (270 vs 210 kg) (Table 2). However, this advantage of Friesian cows was great in 2- (48%) than 3-, 4- and 5-year-old cows (28, 22, and 24%).

Table 2. Least square means for weaning weight (kg) according to breed of sire and breed of dam (Morgan and Saul 1981).

Sire breed	Dam breed		
	Hereford	Friesian	Mean
Hereford	202	269	236
Friesian	218	268	243
Charolais	218	286	252
Brahman	201	257	229
Mean	210	270	

Steer calves were 8.6% heavier at weaning than heifer calves (250 vs 230 kg).

The effect of sire breed on calf weaning weight was small relative to the influence of cow breed, particularly in the progeny of 2- and 3-year-old cows; the weaning weight advantage of the progeny of Charolais sires over the progeny of the other sire breeds from 1971 to 1974 was 4.1, 4.0, 8.9, 10.6%, respectively.

The use of Charolais sires did not show a great advantage on Hereford dams probably due to the lower milk supply from the Hereford dams as well as the death of calves with high birth weights; the mean birth weight of Charolais-Hereford calves which died at birth in 1971-72 was 44.4 kg compared with 32.3 kg for those that survived.

Use of Friesian sires on Hereford cows increased weaning weights to the same extent as Charolais sires (about 8%). However, when used on Friesian cows, Friesian sires did not increase weaning weights above Hereford sires; their calves weighed about 6% less than those from Charolais sires. This is a clear example of the effect of heterosis on calf growth rate, giving a mean estimate of 3.4% heterosis for weaning weight from Hereford-Friesian crossing.

Milk Production

The milk production of Friesian cows was substantially higher than that of Hereford cows (8.9 vs 3.7 kg/day). The small differences in the milk consumption of calves sired by Hereford, Friesian, Charolais, and Brahman bulls were not significant (6.2, 6.4, 6.6, and 6.2 kg/day, respectively).

Growth and Puberty of Heifers

Attainment of puberty by 14-15 months of age is essential if calving at 2 years of age is to be achieved. Heifers that conceive late in the breeding season and heifers that do not calve until 3 years of age reduce the production and feed efficiency of the herd.

At Hamilton, calves were weaned at a mean age of 8 months and heifers were grazed on improved pasture without supplementary feeding.

The progeny of Hereford cows grew faster than the progeny of Friesian cows after weaning (0.46 vs 0.42 kg/day) but the latter were still heavier at 21 months of age (Table 3); the liveweight difference varied from 58 kg in the heifers born in 1971 to 18 kg in those born in 1974.

Friesian-and Charolais-sired heifers grew faster, and were heavier at 21 months of age, than Hereford- and Brahman-sired heifers.

Relative to HH and CH heifers, the FH, HF, FF, and CF heifers reached puberty at a younger age and BH heifers at an older age. Mean liveweight at puberty was lowest in FH heifers and highest in CH and BH heifers. Heterosis in HF and FH crosses for age and liveweight at puberty as -59 days (19%) and -17.4 kg (6%), respectively (P<0.05).

The effect of the dam's milk supply is demonstrated unequivocally by the difference between the HF and FH heifers (Table 3). Clearly a high maternal ability of the dam facilitates the early breeding of the heifer progeny. Brahman-sired progeny reached puberty at a much later age than the progeny of the other sire breeds.

Crossbreeding of suitable breeds can facilitate the success of systems that incorporate first calving at 2 years of age.

Table 3. Growth and puberty traits according to sire breed and dam breed (Morgan 1981).

Genotype	Weaning weight[a]. (kg)	Average daily gain[b]. (kg)	Lwt. at 21 mths of age (kg)	Age at puberty (days)	Lwt. at puberty (kg)
Hereford x Hereford	195	0.444	373	464	290
Friesian x Hereford	212	0.474	402	347	263
Charolais x Hereford	215	0.468	402	470	326
Brahman x Hereford	196	0.449	374	568	336
Hereford x Friesian	260	0.421	428	277	285
Friesian x Friesian	256	0.428	427	298	294
Charolais x Friesian	278	0.432	451	309	313
Brahman x Friesian	244	0.399	401	397	306

a. Adjusted to age of 240 days.
b. Average daily gain from weaning (8 months) to 21 months of age.

Calving Performance of Crossbred Cows

Dam breed did not affect gestation length (mean 289 days). Breed of grand-sire influenced calving difficulty score (F > H, C > B, Table 4), which appeared to be related to the ratio of birth weight to cow weight (group r = 0.92). Breed of grand-sire and breed of grand-dam influenced birth weight (F, C > H > B and F > H, respectively).

Table 4. The effect of dam breed on birth and live weight measurements (Morgan and Clark 1982).

Dam breed	Cow wt. (kg)	Calving difficulty score	Birth wt. (kg)	Weaning wt. (kg)
H x H	476	1.8	35.9	248
F x H	486	2.0	40.3	293
C x H	533	1.8	39.6	272
B x H	493	1.4	34.6	261
H x F	509	1.8	39.5	275
F x F	508	2.0	42.0	303
C x F	560	1.7	42.5	291
B x F	505	1.4	36.1	268
D	**	n.s.	**	**
S	**	**	**	**
D x S	*	n.s.	**	**

D = grand-dam effect; S = grand-sire effect; DxS = interaction; n.s. = non-significant P > 0.05; * = P < 0.05; ** = P < 0.01

The FF and HH cows reared the heaviest and lightest weaners, respectively and the FH and CH cows reared heavier weaners than the other crossbred cows. Weaners from FH, CH, HF, and CF cows were 18.1, 9.7, 10.9, and 17.3% heavier, respectively than weaners from HH dams.

Brahman cross dams had lower birth weight calves and a reduced calving difficulty.

When age at first oestrus, anoestrous intervals, and pregnancy rates are also considered, large increases in total production can be expected from the use of F cross and C cross dams.

Carcass Assessment

Carcasses of weaners from dams with F sires were the heaviest, longest, had the highest dressing percentage, the largest eye muscle area (except for C sired dams), and the greatest fat depth. Weaners from C sired dams had heavier, longer carcasses with larger eye muscle areas that the progeny of H- and B-sired dams. Weaners with F grand-dams had heavier carcasses with a higher dressing percentage and a larger eye muscle area than weaners with H grand-dams. These results show clearly that calves from crossbred cows mated to traditional beef bulls yield heavier carcasses that are not leaner than those from traditional straightbreds (Table 5).

Data on post-weaning growth rates and carcass characteristics of steers are given by Morgan *et al.* (1978). The steer progeny of Friesian dams retained most of their weaning live weight advantage over Hereford dams to 42 months of age. However, sire

Table 5. Effect of dam genotype on carcasses of weaner progeny slaughtered at 9 months of age (Morgan *et al.* 1984).

Dam genotype	No.	Carcass wt. (kg)	Dressing out (%)[a]	Carcass length (cm)	Eye muscle (cm^2)[b]	Fat depth (mm)
H x H	10	128	54.5	86.2	40.9	3.9
F x H	21	167	57.3	93.0	46.5	5.5
C x H	28	156	54.9	90.6	50.0	3.4
B x H	20	140	55.0	87.9	43.8	5.0
H x F	19	151	55.8	90.0	46.2	5.0
F x F	4	194	57.9	97.4	54.8	6.3
C x F	8	173	56.9	93.5	48.8	4.5
B x F	30	153	55.6	91.1	45.1	4.2
Grand-sire (GS)		**	*	**	*	*
Grand-dam (GD)		**	*	**	**	n.s.
GS x GD		n.s.	n.s.	n.s.	n.s.	n.s.

a. Based on 24 h starved live weight; b. Measured at 10/11th rib.
** = P <0.01; * = P <0.05; n.s. = not significant P > 0.05.

breed differences in carcass weight at 42 months were relatively small and non-significant.

Joining Live Weight and Age Effects on the Breeding and Lactational Performance of Hereford × Friesian Heifers

Selecting beef heifers with high weaning live weights enhances the probability of early conception. However, data from Johnsson and Obst (1980) indicate that the plane of nutrition required to achieve the high weaning and pre-mating live weights commonly sought in commercial beef heifer replacements for successful matings at 14 months of age can result in significantly reduced milk yield and calf weaning weights in the first and subsequent lactations.

Table 6 presents the data of Spiker (1982) who compared the productivity of Hereford x Friesian heifers from the dairy industry when reared at different rates of gain to achieve joining at either 12, 15, or 24 months of age.

Heifers joined at 12 months of age tended to conceive later in the joining period ($P < 0.05$), had slightly smaller calves, and weaned significantly ($P < 0.05$) lighter calves than those joined at 24 months of age. Heifers joined at 15 months of age conceived earlier in the joining period ($P < 0.05$) than those joined at 12 months of age, but their calves were the lightest ($P < 0.05$) at the 270 day weaning. Older heifers weaned fatter calves ($P < 0.05$).

A comparison of treatments 2 and 4 in Table 6 highlights the adverse effect of fast growth rate during rearing, on first pregnancy rate and subsequent growth rate of the calf. Pregnancy rate was reduced by 38% and calf weaning live weight by 13%.

Age and Live Weight at Puberty in Bulls (Table 7)

From 7 months of age, semen collection was attempted by electro ejaculation. Puberty was defined as a collection of 50 x 10 6 sperm with at least 10% motile. Small numbers of sperm were observed up to 4 months before puberty but both sperm concentration and motility increased dramatically in the 2 months after puberty.

Bulls with Friesian dams had heavier weaning

Table 6. Rearing system, joining age, and live weights, pregnancy rate and calf weaning live weights for Hereford x Friesian heifers (Spiker 1982).

	Treatment group 1	2	3	4	5	6
Rearing system	Bucket	Bucket	Suckled	Suckled	Bucket	Bucket
Target joining age (mo)	24	24	15	12	12	12
Age at puberty (d)	367	458	<370	201	307	352
Live weight at puberty (kg)	248	258	<289	244	230	242
Joining live weight (kg)	370	319	311	307	261	248
Growth rate to joining (kg/d)	0.46	0.39	—	0.75	0.59	0.56
Pregnancy rate (1st joining)	96	96	88	58	80	76
Calf birth weight (kg)	35.7	32.2	30.8	32.5	31.7	30.4
Calf weaning weight 270 day adjusted (kg)	273	270	223	236	252	246
Fat thickness 12/13th rib (mm)	6.3	5.8	4.6	4.7	4.9	5.7
Pregnancy rate (2nd joining)	83	96	95	92	80	93

Table 7. Age and live weight of bulls at puberty (Cummins 1977).

Breed		No.	Age (mths)	Live weight (kg)
Sire	Dam			
Friesian	Friesian	2	10.6	283
Charolais	Friesian	1	10.6	330
Hereford	Friesian	1	10.5	275
Brahman	Friesian	2	11.5	320
Hereford	Hereford	2	12.3	211
Charolais	Hereford	2	12.2	227
Brahman	Hereford	3	14.0	265

weights and reached puberty at a younger age than those with Hereford dams. In addition, bulls with Friesian dams also appeared to have good libido scores several months before puberty was reached, whereas those with Hereford dams did not develop high libido scores until soon after puberty.

Systems of Beef Production

The per head productivity of beef crossbreds is higher than that of the traditional purebreds. However, what has not been researched is the per hectare productivity differences between crossbred and purebred. Genetic differences in feed intake and efficiency of conversion of the feed, particularly when grazing pastures of variable nutritive qualities, may affect productivity. Environmental differences, particularly those affecting both the amount and nutritive value of pasture available throughout the year(s), will also influence the stocking rate possible to achieve a desired product for sale, e.g. weaner vealers or 2 year-old steers.

Morgan *et al.* (1982) have constructed a simple model to simulate the per hectare productivity of Hereford (HH), Angus x Hereford (AH), and Friesian x Hereford (FH) cows calving in autumn. Relationships between stocking rate (SR) and cow performance were derived from previous results for Hereford cows and postulated for AH and FH cows, all mated to HH bulls.

This model predicts (a) that maximum production/ha occurs at 1.55, 1.65, and 1.45 cows/ha for the HH, AH, and FH cows and (b) that crossbred cows will produce substantially more beef/ha than straightbred cows, except that the relative productivity of FH cows will decline sharply at stocking rates (SR) above the optimum.

The relationship between gross margin (GM/ha) and SR suggested that the maximum GM/ha was predicted to occur at approx. 1.3, 1.2 and 1.1 cows/ha for HH, AH, and FH cows, respectively. The lower optimum for AH relative to HH cows is due entirely to the assumed discrimination against store HAH weaners, which begins to reduce returns at 1.2 cows/ha. Despite this discrimination, GM/ha for AH cows was higher than those for HH cows at all SR and was 27% higher at the maximum GM. The FH cows had the highest GM/ha at low SR but the lowest GM at high SR. The maximum GM/ha of FH cows was similar to that of AH cows (i.e. approximately equal to 27% higher than that for HH cows). The maximum GM/ha of all breeds occurred at a SR about 20% less than the biological optimum SR (i.e. the SR producing the maximum weaning weight/ha).

This simulated model is now being tested in real life at Hamilton.

A model of a self-replacing beef herd in western Victoria was computed by Spath *et al.* (1984) who simulated the effects of calving time and SR. Pregnancy rates, weaner live weights, supplements required, and GM/ha were calculated. The SR was about 1.25 cows/ha for winter calving; the maximum GM was about $25 and $35/ha higher for winter than for summer or autumn calving respectively; increased SR caused a curvilinear decline in pregnancy rates and a linear decline in weaner and steer live weights, but an exponential increase in requirements for feed supplements.

Beef production at pasture will always be dependent upon seasonal conditions, unless a system of supplementary feeding is instituted that will maintain cattle at the appropriate live weight and body condition score to allow them to reproduce and produce milk and meat.

The extent of supplementary feeding will depend upon the nutritive quality and availability of such feed, its economic cost, and the alternative uses to which this feed or the land on which it is grown could be put.

Land use for food production therefore becomes a very important question. Figure 1 from Bishop *et al.* (1975) indicates effective rainfall and distribution of beef cattle/sheep. Estimates of pasture dry matter are also given in graphic form in Figure 2 for Victoria.

A systems approach that incorporates Trees/Crops/Pasture/Livestock (sheep, goats, cattle) will give the proper perspective of how crossbred cattle

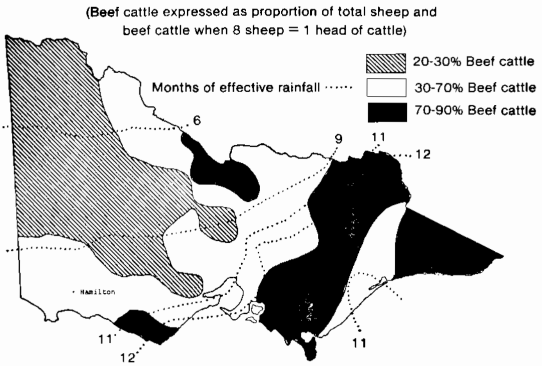

Fig. 1. Ratio of beef cattle to sheep on pasture and the period of effective rain. Reference: The genetic improvement of cattle for beef production (Bishop *et al.* 1975).

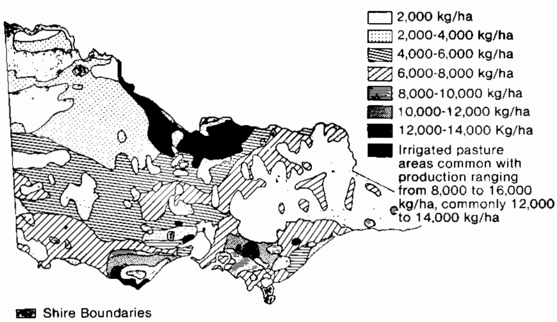

Fig. 2. Pasture dry matter — average annual production. (Map derived from information supplied by the Districts).

will fit into the Victorian environment both biologically and economically. In the same way computer systems (models) can be used to determine the relative use of land areas in overseas countries with different environments and human populations.

Acknowledgements

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Breed Evaluation Research in the Subtropics of New South Wales

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THE breed evaluation program of the Department of Agriculture of New South Wales (N.S.W.) was established at the Agricultural Research and Advisory Station, at Grafton (latitude 29° 42'S). This centre is located within the Australian subtropics but is part of a larger agricultural region that contains nearly one million cattle, or 18% of the N.S.W. herd. The cattle tick (*Boophilus microplus*) is excluded from the subtropical districts of N.S.W. by a quarantine and dipping-control policy.

The majority of cattle are grazed on pastures that consist of native and naturalized grasses that have in common the features of low digestibility, low nitrogen (N) content, and high contents of structural carbohydrate and lignin. The pattern of growth of these pastures, and the performance of British breed cattle (e.g. Hereford, Shorthorn) are shown in Table 1 for a 12 month cycle.

Notably, most cattle are unable to maintain live weight from April to October.

Initially research at Grafton aimed at improving nutrition through improved pastures. Later the scope of the work broadened to isolate the factors restricting production of the existing breeds, and to consider alternative genotypes of cattle that were more suited to the environment.

The breeding work at Grafton has developed in a number of stages:

1. Firstly, a broadly based genotype x environment evaluation was initiated to determine the extent to which the performance of the wide range of genotypes available differed over the range of environments likely to be confronted in N.S.W. This program was based on first-cross progeny of different breeds mated to Hereford females.

2. Subsequently the performance of quarter-bred (backcrossed to Herefords) animals of the same range of genotypes was examined in a range of environments.

3. Currently, crosses of a number of *Bos indicus* breeds are being compared for use in the subtropics, since earlier results indicated that *Bos indicus* crosses performed best in this environment.

4. Further, the proportion of *Bos indicus* genes required for 'optimum' production in the subtropics is being examined over the range of zero to 100%, using Brahman and Hereford as the base breeds.

5. The importance of recombination loss among F_2 and F_3 populations needs to be established for *Bos indicus* — *Bos taurus* crosses in the tropics and this is being done in collaboration with the Queensland Department of Primary Industries and CSIRO at Rockhampton.

6. Studies of the underlying reasons for observed differences in performance have accompanied the breed evaluation program. The nutrition research program conducted at Grafton has been most comprehensive in defining factors limiting the productivity of Hereford cattle grazing native pastures, and it is proposed to extend this to other genotypes and their crosses.

The Breed Evaluation Program

Genotype × Environment Evaluation

(1) Aim: To examine the relative performance of crosses of widely different breed types over a range of environments in N.S.W.

(2) Design: This program is based on Hereford females using three breeds as sires of first-cross calves (Table 2). These breeds represent distinct breed types: the large European breeds — Simmental (S); the dairy breeds — Friesian (F); and the *Bos indicus* breeds — Brahman (B). Poll Hereford and Hereford breeds are included as a control herd to provide a comparison with normal breeding practice in the region.

Hereford females were artificially inseminated to 50 sires of each breed for 5 years, producing a total of 920 calves.

The Hereford and F_1 steer progeny were grazed in a number of regions in N.S.W. Hereford and F_1 heifers were retained at Grafton for breeding and

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Table 1. Subtropical grasslands -growth cycle of pastures.

OCT.-DEC.(new growth)

NOV.-JAN.(rapid growth)

JAN.-JUNE (seeding maturation)

APRIL-OCT. (pasture deterioration)

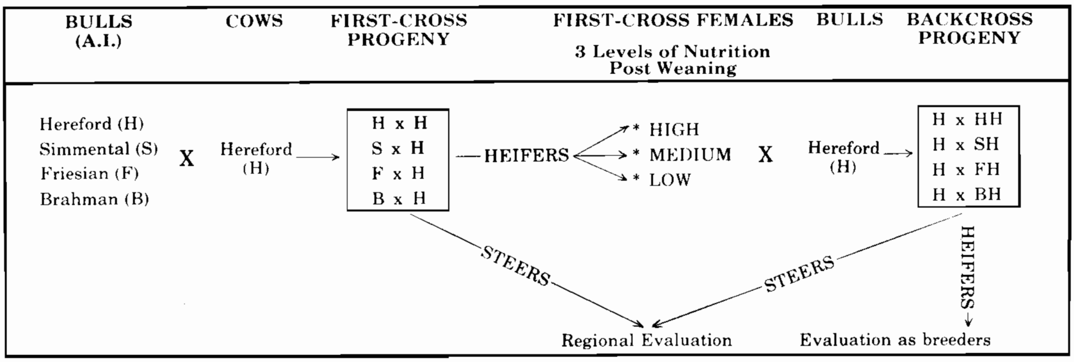
PHASE	I	II	III	IV
	Unreliable rain: Quality highest	Main period of growth. Quality suffers from slow N mobilization	Reliable rain; 62% of total	Temperature and Moisture unfavourable Quantity and quality low
OMD %	60	55	50	40-45
N (g/kg DM)	13	11	9	7

Main lactation period

Rapid weight gains to Feb. Slow gains to April. Weaning March-April

Period of liveweight loss Calving July-Sept.

Table 2. Design of G x E and quarter-bred evaluations.



grazed on three pasture types to determine their performance over a range of nutrition levels designated as High, Medium and Low.

a. High — improved legume/grass pasture plus irrigated, high-nitrogen ryegrass on alluvial flats and protein supplements when necessary.

b. Medium — improved grass pasture (Kikuyu grass and Rhodes grass) with some legume.

c. Low — native and naturalized grasses on soils of low fertility.

All Hereford and F_1 females were backcrossed to Hereford bulls. At a later stage, outcrossing of the HxH and F_1 females to a terminal sire will be considered.

(3) Performance of First-Cross Calves

Preweaning: The survival and growth of first-cross calves to weaning was superior to that of Herefords, resulting in an increase of 9-19 kg of calf weight at 7 months (per cow calving), depending on the cross involved (Barlow *et al.* 1978; Barlow and O'Neill 1978, 1980). The relative performance of the genotypes varied depending on the seasonal conditions prevailing at Grafton during the pre-weaning period (Barlow and O'Neill 1980).

Post Weaning Growth: Large interactions were observed between genotypes and environment for the growth of heifers and steers after weaning. The results presented in Figure 1 indicate the nature of this interaction among heifers.

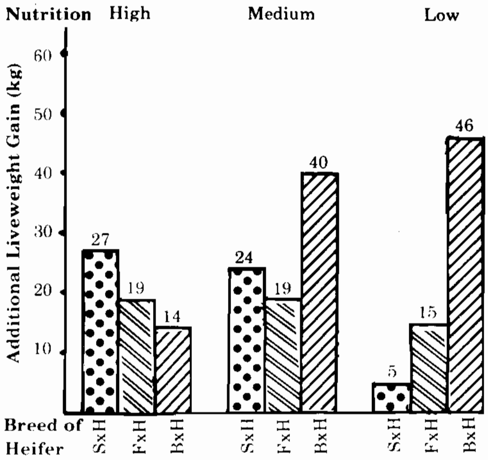


Fig. 1. Additional live-weight gained by first-cross heifers compared with the H x H, from weaning to 20 months on different levels of nutrition.

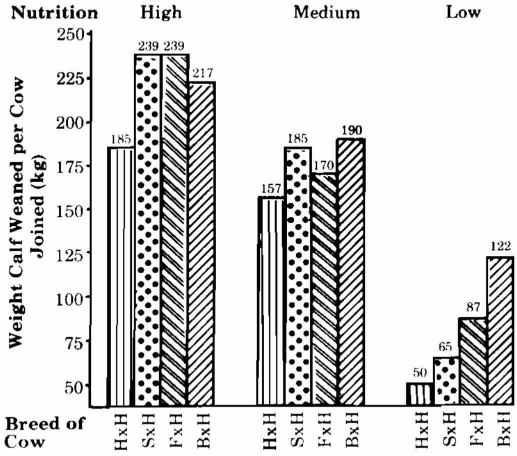


Fig. 2. Weight (kg) of calf weaned per cow joined.

- First-cross heifers grew faster than Herefords on all levels of nutrition.
- On the High level, SxH grew the fastest.
- The BxH heifers grew faster than SxH and FxH heifers on both the Medium and Low levels of nutrition.

This pattern was similar to that among the steers grown in different regions of N.S.W., with the SxH growing fastest under favourable conditions and the BxH performing best when environments were unfavourable for growth of Herefords.

Performance of the First-Cross Cows at Grafton: Large interactions have been observed among first-cross cows also, with the pattern being similar to that for the growth of young stock, as described previously. This is well illustrated by the results given in Figure 2.

The weight of calf weaned per cow joined is a combination of weaning performance and weaning weight.

- On the High level, both the FxH and SxH weaned the highest total weight of calves.
- On the Medium level, the BxH and SxH weaned the highest total weight of calves.
- On the Low level, the BxH weaned the highest total weight of calves.

The Hereford and first-cross cows are being retained at Grafton to evaluate their lifetime performance, and backcross progeny produced by them have formed the basis for further evaluations (see later). Already there are indications of large differences in life expectancy between genotypes with 26% of the HxH cows having left the herd compared with 22% of SxH, 20% of FxH, and 12% of BxH. The major reasons for departure have been cancer of the eye and infertility.

Currently, a project is underway to estimate dry matter intake of the mature cows at pasture, and the milk consumption of their calves. These data will be used in conjunction with the production data to provide estimates of production per hectare.

Relative Performance of Quarterbred and Straightbred Cattle

(1) Aim: To evaluate the relative performance of ¼ Simmental ¾ Hereford, ¼ Friesian ¾ Hereford, ¼ Brahman ¾ Hereford, and straightbred Herefords (4/4) in a range of environments. Comparison of these results with those from the GxE study will provide an indication of the effect of production of reducing the proportion of introduced genes from 50% to 25%.

(2) Design: Hereford and backcross weaner heifers (progeny of first-cross and Hereford cows sired by Hereford bulls), which were raised until weaning at Grafton in three groups (on High, Medium, or Low nutrition levels) are located at three sites on coastal N.S.W. At each location all heifers are grazed in one herd, joined at 2 years of age and will be given four opportunities to calve. Hereford sires are being used and the progeny will be compared at weaning.

Contemporary quarterbred steers have been grazed at three other locations in N.S.W.

(3) Results: Early indications from this work are that the difference between first-cross and quarterbred animals may not be as large as anticipated.

Evaluation of a number of *Bos indicus* Breeds in the Subtropics

(1) Aim: To compare alternative *Bos indicus* breeds with the Brahman for use in the subtropics of N.S.W.

(2) Design: This program was based on Hereford females using three breeds as sires of first-cross calves. These breeds were the Brahman (B), and Braford (Bf) (a fixed interbreed derived from the Brahman and Hereford), and the Africander (Af).

One hundred and fifty Hereford females were inseminated to approximately 10 different sires of each breed in each of 3 years. First-cross heifers are retained for breeding in the subtropics on improved pastures, and will be joined at 2 years of age to Braford and Belmont Red (BR) (a fixed intercross derived from the Africander) sires. Females of the F_2 generation will also be retained for breeding along with contemporary F_1 Brahman x Hereford females. It is proposed to evaluate the growth and carcass performance of steers mostly in subtropical locations.

(3) Results: The BxH first-cross heifers and steers grew faster than other crosses in the subtropics. Among young females, the weaning percentage of first-cross AfxH has been about seven percentage units greater than that of the other crosses, while the weaning weight of calves out of BxH females has been 35 kg greater than the mean of calves from BfxH and AfxH females.

Evaluation of the Proportion of *Bos indicus* Genes Required for the Subtropics

(1) Aim: To determine the approximate proportion of Brahman genes required to give optimum performance for growth and reproduction in the subtropics.

(2) Design: Females in the GxE program are being mated to Hereford and Brahman bulls for 3 years (1982-1984), to produce HxH, ¼B ¾H, ½B ½H, and ¾B ¼H calves along with BxBV calves from a line of Brahman females now grazing contemporaneously with the GxE females. Approximately 30 sires of each breed will be used over the 3 year period.

Both the steer and female progeny will be retained for evaluation in the subtropics. Females will be mated to Brahman, Hereford, and first-cross sires.

No results are available from this project.

Recombination Loss in Crosses in The Tropics

This project aims to measure any change in production that occurs when F_2 and F_3 populations of Brahman x Hereford crosses are produced from *inter se* matings among F_1 and F_2 crosses, respectively. From a breeding viewpoint, this is probably the most important question still to be answered, as the advantages of F_1 populations are well established.

CSIRO and the Queensland Department of Primary Industries, Rockhampton are the senior collaborators in this project, and details of the project will be reported in their contributions to this Workshop.

Nutritional Restriction on Growth of Hereford Cattle Grazing Native Grass Pastures in the Subtropics

As discussed previously, *Bos taurus* cattle appear to be affected more by the low nutritional value of pastures than *Bos indicus* cattle or their crosses. To understand the nature of this restriction, a series of experiments was initiated to examine the effects of a readily available source of nitrogen to the rumen and of slowly degradable protein, on metabolism, feed intake, and live weight change of young Hereford cattle.

Experiment 1: Chaffed hay was made from native pasture cut in winter and fed in pens to young Hereford steers, of 145 kg $\pm$ 6 kg live weight. Supplements of urea sprayed onto the hay and a supplement of 400 g/d of a pelleted protein meal that was only slowly degradable in the rumen were provided as indicated in Table 3.

The results indicate that Hereford steers eating a basal diet typical of what is available during winter months have low rumen ammonia concentrations and low feed intake. It is clear that supplying extra nitrogen increases feed intake and consequently live weight change. Urea was a suitable supplementary form of nitrogen but the protein supplement increased live weight gains further. Since this supplement contained both energy and slowly degradable protein, a second experiment was initiated to understand the importance of these two components.

Table 3. Effect of supplements on nitrogen and hay intake of cattle on the low quality basal diet, on rumen ammonia concentration, and on liveweight change during 49 days (experiment 1).

	Urea (g/d)					Protein meal	SEM
	0	15	23	42	53		
Nitrogen intake (g/d)	18	28	34	41	43	46	3**
Rumen ammonia (mg N/L)	8	54	103	126	152	45	11**
Hay intake (g OM/d)	2 530	3 010	3 110	3 020	2 870	3 130	72**
Liveweight change (g/d)	-50	260	270	160	230	390	55**

**P < 0.01

Table 4. The comparative effects of nitrogen with or without energy supplements and non-degradable protein on rumen ammonia concentrations, feed intake, and liveweight change of cattle on a low quality basal diet.

	0	55 Urea[a].	55 Urea 400 MF[b].	26 Urea 100 MF 150 FTC[c].	280 FTC	SEM
Nitrogen intake (g/d)	32	56	60	65	67	
Rumen ammonia (mg N/L)	18	226	239	200	91	
Hay intake (g OM/d)	4 020	4 370	3 990	4 350	4 290	33**
Liveweight change (g/d)	100	290	340	550	600	56**

a. Refers to 55 g urea/steer/d.
b. Refers to 400 g maize flour/steer/d.
c. Refers to 150 g formaldehyde-treated casein/steer/d.

Experiment 2: The aim was to compare the effect of supplementary urea with or without an energy supplement (maize flour) with a supplement of non-degradable protein (formaldehyde-treated casein) on hay intake, rumen ammonia concentration, and live weight change. Hereford steers were penned and allocated to the five treatments as listed in Table 4. The pasture was cut in March-April and included native and other legumes (e.g. *Glycine* spp and *Aeschynomene falcata*).

The results indicate the importance of nitrogen in the diet but clearly demonstrate the beneficial effects of non-degradable protein in providing essential amino acids to the intestine (Egan 1984a).

Field Evaluation: The results of experiments 1 and 2 highlight the importance of both rumen soluble nitrogen and additional dietary protein, available for absorption by the intestine, in overcoming the restriction of growth that occurs when Hereford cattle are fed hay made from native grass pastures, especially during winter months. To test this hypothesis under grazing conditions, a field supplementation trial was undertaken over 5 years. Results were reported by Hennessy (1983). In summary, productivity of Hereford cattle was increased by 135% by supplementing them for 150 days during autumn-winter with protein meal pellets. Calving rate was increased from 44 to 83%, cow live weight from 320 to 382 kg, and weaning weight of calves from 138 to 172 kg (230-day adjusted) by the annual feeding of supplements.

The Future: Emphasis of the nutritional research program to the present time has been on understanding the reasons for Hereford cattle having such low productivity on the native grass pastures of the subtropics. Now the program is focusing attention on the attributes of the *Bos indicus* and *B. indicus* x *B. taurus* cattle that lessen their susceptibility to low N intakes whilst eating forages of low digestibility. For example, Egan (1984b) suggested that *B. indicus* cattle had lower endogenous N excretions than *B. taurus* cattle. However, no difference was observed between *B. indicus* x *B. taurus* and *B. taurus* cattle in N excretion after 65 days on a low quality diet at Grafton (D. Hennessy, R. Barlow, J. Herlihy, and P. Williamson, unpublished observations) with both breed types having net losses of 1 g N/d.

Attention has been drawn to the ability of *B. indicus* cattle to recycle urea N to the rumen (Vercoe 1969). However, measurements made in Hereford cattle indicate that they too are highly efficient. Hennessy (1984) reported that 98% of urea N synthesized in Hereford cattle on a low quality diet was degraded in the alimentary tract with 58% of the degradation being in the rumen, the site where urea N is required. This is a higher proportion than that reported for Brahman cross cattle on a low quality ration (Norton *et al.* 1979), which had urea production rates only half that of the Herefords.

There are many aspects of comparative nitrogen metabolism unknown, and further studies are planned at Grafton to understand what aspects differ and what advantage these differences many confer on *B. indicus* type cattle. Support has been sought from ACIAR for a collaborative study between the Academy of Agricultural Science, in Guangdong Province, Republic of China, and ourselves, (Agricultural Research Station, Grafton) to extend this work to the Zebu cattle of S.E. Asia.

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Understanding Genotype/Environment Interactions: The Rockhampton Experience

D.J.S. Hetzel*

GENOTYPE x Environment (G x E) interactions can be defined as occurring when genetic and environmental effects are not additive, such that the relative performance of genotypes varies in different environments. Genotype evaluation is carried out under the expectation that G x E interactions will occur; otherwise the relative performance and ranking of genotypes in one environment would hold across all environments. Thus the planning and conduct of genotype evaluations is essentially a study of the nature and extent of a G x E interaction.

The ultimate aim of genotype evaluation studies should be to indicate the optimum combination of genetic and non-genetic inputs required to maximize economic return or efficiency for a given climatic situation. It is customary to refer collectively to non-genetic and climatic factors as environmental factors. Non-genetic inputs will include management practices such as length of mating period, number of watering points, weaning times, stocking rates, and frequency of treatment for specific parasites and diseases. Climatic aspects of the environment will largely determine the quality and quantity of feed, the absolute numbers and seasonal incidence of parasites and diseases, and the extent of other stresses such as heat and humidity.

Although research at CSIRO, Rockhampton has not specifically been aimed at the evaluation of different genotypes, such information has been collected in the course of studying genetic aspects of tropical beef production. Most importantly, a general approach to analysing genotype differences has evolved that is of general relevance to genotype evaluation. In the following sections, studies leading to the gross characterization of the Belmont genotypes will be briefly reviewed and the relevance to genotype evaluation will be discussed. A more detailed review of research at Rockhampton is included in Turner (1975).

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Origin of the Belmont Lines

The basic aim in establishing the different lines of cattle at the National Cattle Breeding Station, Belmont was to provide between-genotype genetic variation for the study of the physiology of adaptation (Kennedy and Turner 1959). This followed the recognition that *Bos indicus* breeds could improve survival and production of the local *Bos taurus* cattle. The breeding program that was followed is shown in Figure 1.

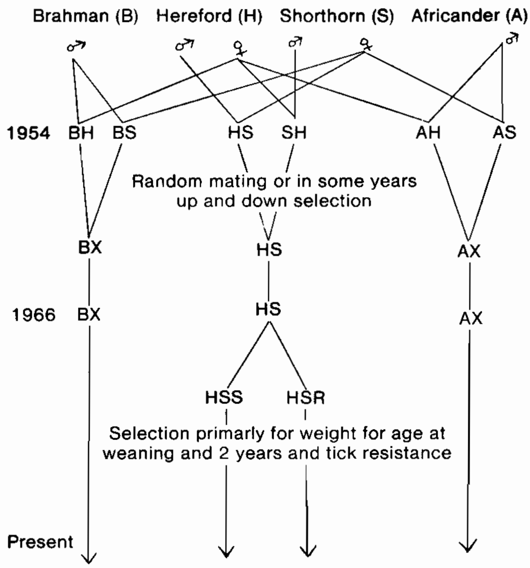

Fig. 1. Simplified mating design for the derivation of the Africander cross (AX), Brahman cross (BX), and Hereford-Shorthorn (HS) lines at Belmont.

The numbers of base Shorthorn cows and bulls and Hereford cows and bulls were 200, 4, 300, and 6, respectively. Because of quarantine restrictions, Africander cattle could not be imported from South Africa. Accordingly, eight bulls and two cows were purchased from King Ranch, Texas, USA. This sample represented the only importation of Africander genes into Australia. Five of the bulls, all of which were highly inbred, were used to start the AX line. Four Brahman bulls, three of which were progeny from line breeding to a common ancestor (Lampkin and Kennedy 1965) were the founders of the BX line. Thus, it is apparent that the AX and BX lines were based on a small genetic sample of the respective sire breeds. The lines were closed from the outset and random breeding of F_1 and subsequent progeny was practised.

After the F_2 generation, the Hereford and Shorthorn crosses for each line were intermated to form the BX, HS, and AX lines. In 1966, selection was initiated in all lines except for a group of HS animals, which continued to be randomly mated. Selection pressure has primarily been on pre-weaning growth, tick resistance, and weight for age at 20-24 months, although at times post-weaning gain, feed intake, fertility and heat tolerance (HS line only) were taken into account (G. Seifert, pers. comm.). Selection pressures have been mild due to general laboratory demands. In some years, single trait up and down selection was practised.

Studies at Rockhampton referred to in the next section used animals from the AX, BX, and HS lines. In addition, a small line of high grade Brahman, maintained as a stud herd until the early 1970s, has also supplied animals for experimental studies.

Genotype Evaluation

At Rockhampton, analysing genotype differences has passed through three phases. The first phase involved comparisons solely in terms of production traits in the normal grazing environment. There were a number of studies, some based on small numbers of animals, but each confirmed the greater productivity of Zebu crosses. Lampkin and Kennedy (1965) reported that from 1954 to 1965, F_1 Brahman cross heifers at 2 years of age were 80 kg heavier and F_1 Africander cross heifers were nearly 56 kg heavier than F_1 heifers from the Hereford-Shorthorn lines. There were no differences between heifers born out of Hereford or Shorthorn cows for any of the sire breeds. Kennedy and Chircher (1971) reported a similar ranking for steers from each of the lines. From data collected between 1964 and 1968, F_2 and F_3 Zebu crosses were 15-20% heavier at 18 months of age than HS animals (Table 1). Two other reports confirmed the relative ranking of the genotypes with regard to body weight at about 2 years of age, both for F_1 and F_2 progeny (Seifert and Kennedy 1972) and over the 1969 drought (Frisch 1973).

In none of the studies referred to were the authors able to do more than speculate as to why the breeds differed in growth rates. The elucidation of the factors required examination of the component traits. The component traits that have been studied in more depth are ecto-and endo-parasite resistance, heat tolerance, response to poor nutrition, and in a non-grazing situation, feed intake and metabolic rate. Studies have concentrated on growth as the production trait.

Table 1. Body weights (kg) at birth, weaning, and 18 months of age of F_2 and F_3 Africander cross (AX), Brahman cross (BX), and Hereford-Shorthorn (HS) heifers (Kennedy and Chircher 1971).

Genotype	Birth	Weaning	18 months
AX	29.6	183	283
BX	28.4	193	295
HS	30.8	169	244
Total Number of Animals	601	580	497

Breed differences in resistance to ecto- and endo-parasites were first studied by Seifert (1971) and Turner and Short (1972). Although there were some differences in the magnitude of the assessed parasite resistance and tolerance between the studies, the relative genotype differences were similar (Table 2). Differences between the genotypes were considerably reduced when parasites were controlled. There seemed to be little need to devise ways of reducing the parasite burden in BX animals (in fact the helminth burden appeared to have no effect on production) while AX and HS cattle would give significant responses. Both authors stressed that responses were very dependent on nutritional conditions. Neither of these studies permitted the interaction between tick and helminth infestations to be determined.

Some of the more obvious components of the physical environment in the tropics are high ambient temperature, solar radiation, and at times high humidity. However, at present it is not possible to estimate separately the ambient heat load, the amount of heat produced as part of digestive and metabolic processes, and the heat loss through the various dissipatory mechanisms. In grazing animals it has only been possible to measure the net results of heat input and output, i.e. body temperature. Animal responses in climate room studies do not accurately reflect the field situation. Thus the effect of heat on production and the importance of heat tolerance as an animal characteristic has been difficult to define.

Table 2. The effects of the cattle tick (*Boophilus microplus*) and gastrointestinal helminths on the growth of Africander cross (AX), Brahman cross (BX), and Hereford Shorthorn (HS) cattle.

Genotype	Untreated group		% difference[a] in weight gain between untreated group and group treated for:	
	Mean no. ticks/side	Mean no. eggs/g faeces	ticks	helminths
Seifert (1971)[b]				
AX	10	169	29	8
BX	3	222	-10	-9
HS	17	180	90	55
Turner & Short (1972)[c]				
AX	30	144	10	22
BX	27	118	3	1
HS	88	112	44	29

a. Expressed relative to weight gain for untreated group; positive sign indicates higher weight gain for the treated group.

b. Treated every 2 weeks for 12 months.

c. Treated every 3 weeks for 6 months.

Early work at Rockhampton centred on the characteristics of the skin and coat of British animals in relation to insulation and number, size, and activity of sweat glands, e.g. Turner (1962). More recent work showed that, even in the supposedly heat tolerant Brahman and Zebu crosses production is lowered by heat stress. Turner (1984) found that the regression of growth rate from birth to 18 months of age on rectal temperature was -0.04 kg/day for each degree centigrade rise and did not differ between the genotypes studied. Turner (1982) also reported that the relationship between calving rate and rectal temperature was negatively curvilinear, possibly due to effects on early embryo mortality. It is important to note that there are significant differences in the body temperatures of genotypes measured under the same heat stress (Table 3), indicating differences in heat tolerance.

However, the effect of increased body temperature was similar in all breeds. There is clearly considerable incentive to reduce the net heat load on an animal although the scope is greater in Zebu crosses than Brahman cattle. However, the returns will not necessarily be linear with respect to traits such as fertility (Turner 1982).

Table 3. Mean (retransformed) rectal temperatures of Brahman (B), Africander cross (AX), Brahman cross (BX), and Hereford-Shorthorn (HS) heifers from the 1976 and 1977 drops (Turner 1984).

Genotype	Rectal temperature (°C)	
	1976	1977
B	39.33 (10)[a]	39.29 (13)
AX	39.49 (50)	39.31 (59)
BX	39.38 (16)	39.45 (43)
HS[b]	40.06 (8)	39.81 (13)
Standard deviation	0.37	0.28

a. Number of animals in parentheses.

b. From the randomly selected line.

Low quality feed (less than 1% nitrogen content) during much of the dry season is a feature of Australian tropical areas. Thus, the ability of cattle to maintain weight or minimize weight loss during this period as well as during prolonged droughts is related to feed intake and maintenance requirements (proportional to metabolic rate). From pen studies, Brahman crosses have lower fasted metabolic rates that either AX or HS animals (Frisch and Vercoe 1969) and the Zebu crosses maintained a higher body weight on a fixed level of low quality feeding (Frisch and Vercoe 1977). Under grazing conditions during a drought year, similar rankings in body weight of the genotypes applied (Frisch 1973).

The estimation of one of the major component traits for any production trait, i.e. feed intake, has been to date restricted by the inability to measure the trait under grazing conditions. Recent advances with controlled release capsules are promising. Past studies have measured feed intake of low and high quality roughages in pens where animals were free from the field stresses of parasites and heat. British (HS animals) had higher feed intakes per unit body weight on high and low quality hay, and higher fasted metabolic rates than Zebu crosses (Frisch and Vercoe 1977), although compensatory growth in HS animals may have influenced the relative values.

The third phase of these studies has involved the simultaneous evaluation of traits related to stress resistance, as well as the determination of voluntary feed intake of high quality feed and fasting metabolic rate (Frisch and Vercoe 1984). The Brahman breed was included to provide both parental genotypes of the BX. In this study, the response of the genotypes to environmental modification was determined by comparing contemporaneously untreated animals with animals treated for ticks and gastrointestinal helminths. Genotypic differences in resistance to stresses were demonstrated by recording parasite/stress levels in untreated animals and examining responses to treatment. Other stress indices such as rectal temperatures and incidence of bovine infectious keratoconjunctivitis (BIK) were monitored.

In the field, the Brahman breed was most resistant to parasites and had the lowest rectal temperatures and incidence of BIK (Table 4). It had a growth rate very similar to the BX and responded least to parasite control. If the response to environmental stresses were linear, it would have grown at a faster rate than BX or HS animals in a more stressful environment. As previously reported, the growth potential (growth rate with minimal environmental stresses) of the Brahman was well below that of the BX, i.e. the BX responded more when stresses were alleviated. Since the tick and helminth stresses were not removed factorially, it was not possible to estimate the interaction. In an ongoing trial, this is being measured (J.E. Frisch, pers. comm.).

The results of the Rockhampton work led to the conclusion that production in any environment is a function of two factors which are, (1) the performance of the genotype in a stress-free environment, (referred to as genetic potential), and (2) its degree of adaptation to the environment (Frisch 1976; Seebeck 1977). The second factor determines the amount by which production is reduced due to incomplete adaptation to the environment, i.e. due to the genotype not being totally resistant or tolerant to the environmental stresses. Where there are no environmental stresses or where they are minimal, genotypes will rank according to the first factor. If the relative performance of the genotypes changes when one environmental stress is imposed, this is due to differences in their resistance to this environmental stress. If more than one stress is acting, the sum total of resistance to all stresses is responsible for changes in relative ranking. These principles will be discussed in the context of planning genotype evaluations, leading to an understanding of why G x E interactions do or will occur.

Relevance to Genotype x Environment Interactions

The study of G x E interactions can be conducted at three levels of complexity (Figure 2). At the first level are production traits, i.e. traits that measure important production parameters in a beef cattle enterprise, such as reproductive rate, growth rate, mortality, and carcass yield. Variation between genotypes in production traits can be partitioned into variation in component traits, i.e. the second level. Component traits that account for the variation in production traits in the absence of any environmental stresses may be termed direct component traits, e.g. feed intake and ovulation rate are direct components of reproductive rate; feed intake, nutrient partitioning, and maintenance requirement are direct components of growth rate.

In the presence of one or more environmental stresses, the expression of the direct component traits may be modified and genotype differences may be altered. Thus, there are a series of adaptive (component) traits, corresponding to the resistance of genotypes to each of the important environmental stresses, which through the direct component traits affect the level of the production trait. In the Rockhampton environment, resistance to stresses such as heat, ticks, gastrointestinal helminths, dry season nutrition, and diseases such as BIK are important (Frisch 1976).

At a third level, genotypic variation in the biochemical, physiological, and immunological processes, which contribute to the direct and adaptive component traits, can be identified. These may be termed regulation traits. For example, between breeds differences in thermoregulatory efficiency have been shown to be partly due to the responsive-

Table 4. Mean body weight (kg), tick count (ticks/side), faecal egg count (eggs/g), and rectal temperature (°C) of Brahman (B), Brahman cross (BX), and Hereford-Shorthorn (HS) bulls untreated (U), and treated (T), for ticks and gastrointestinal helminths (Frisch and Vercoe 1984).

Genotype	No. of animals		Body wt. at 15 mo		Tick count		Faecal egg count		Rectal temperature	
	U	T	U	T	U	T	U	T	U	T
B	9	7	251	282	4	0	337	16	39.1	39.1
BX	16	19	247	313	13	0	460	39	39.2	39.2
HS	16	21	172	283	26	0	664	53	39.5	39.7

ness of sweat glands although the actual control mechanism is still unclear (Finch *et al.* 1982).

In past studies, many researchers have gone no further than to point out that G x E interactions exist for production traits. In a recent example Burns *et al.* (1979) tested two lines of Hereford cattle, selected in different locations in a cross-over design. Line x location interactions were detected for most traits, with lines performing best in their home environment. However, only production traits, i.e. weights, reproduction, and mortality were measured and thus the only conclusion possible was that genetic adaptation to the local environment was important. This approach therefore provides little understanding of why the G x E interaction occurred and under what types of environments it might be expected to occur again. The information gained in such studies has little general application.

On the other hand, the Rockhampton work suggests that for information to be of greater value, comparative evaluations of genotypes should be conducted not only in terms of production traits but also in terms of many of the component traits that collectively determine production. In this way, genotypes can be characterized in terms of their direct and adaptive components of production (Figure 2). Relative levels of adaptive traits are an indication of how stressful the environment is for each genotype, given a similar challenge. When the genotypes are compared in another environment, (e.g. in which one of the stresses has been increased, reduced, or alleviated), relative responses indicate the magnitude of the stress in terms of the production traits, as well as the scope for genetic or environmental change for each of the genotypes.

The Rockhampton approach has also incorporated the study of the between-breed genetic differences in physiological and biochemical processes involved in component traits. In attempting to understand the biological architecture of the component in question, manipulation, either by genetic or environmental means, should result in a more productive animal. Much remains to be done in this area. This third level of study is not an essential part of understanding G x E interactions in order to extrapolate to other environments, but it does provide insights into what future changes might be made in the production system to increase productivity.

General Principles for Genotype Evaluation

The Rockhampton experience suggests that there are a number of important general principles for genotype evaluations.

1. First, there is a need to be able to identify the major environmental stresses in the region where the evaluations are to be conducted. The relative magnitude of these stresses will vary from one area to another but in order to design evaluations to test the

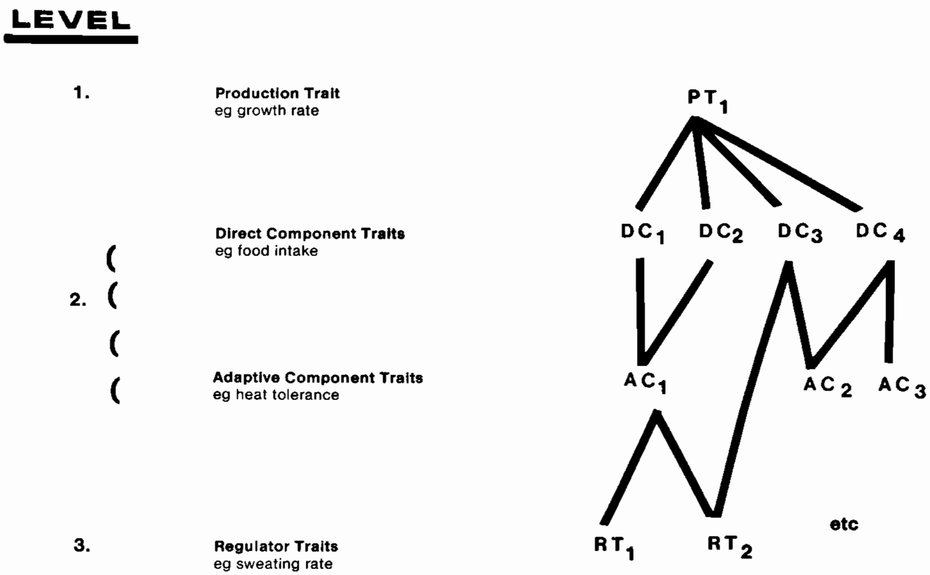

Fig. 2. Schematic representation of the partitioning of a production trait into direct and adaptive component traits and regulator traits.

response of genotypes to the stresses, the major stresses must be identified, initially perhaps by experience.

2. Evaluations should be comparative since it is the relative production and relative values of the direct or adaptive components traits that are of interest. So that evaluations from different areas, regions or countries can be linked to some extent, it would be highly desirable to use one reference breed in all evaluations. Such a reference breed should be widely available, well characterized, and reasonably resistant to the range of environmental stresses that might be encountered. Probably the breed that would best qualify on all accounts would be the Brahman. However, it is possible that in many situations the inclusion of a reference breed would add little information and a great deal of cost to a particular experiment. Thus, it may be more sensible to have several reference breeds, e.g. one for each continent, the relative attributes for which have been well documented.

3. Evaluation only in terms of production traits, e.g. growth rate and reproduction is of limited value for extrapolating to other environments. Evaluations should involve measurement of component traits in such a way that relative resistance/tolerance levels can be defined and responses to varying severities of stresses can be measured. Where parasites or diseases are unique to a region or country, information on relative productivity in the absence of the parasite or disease will be most useful for extrapolation.

4. The environment in which initial evaluations should be carried out is the appropriate production environment where the major environmental stresses are active. To determine relative resistance/tolerance of the genotypes, stresses should be varied individually or in a factorial manner. Although it is not possible to identify cause and effect, i.e. relate the levels of production traits directly to the levels of the component traits, relative measures will be useful.

Frisch and Vercoe (1984) advocate the comparative evaluation of breeds, not only in terms of resistance to stresses but also in genetic potential, being measured in the absence, or with minimal levels, of stress. Although such an evaluation would allow conclusions to be drawn about the relative expression of potential in any given environment, it does not allow determination of the relative importance of resistance to each environmental stress, or the interaction between stresses. Such information will only come from a factorial design as outlined earlier. Measurement of actual direct components, e.g. food intake, metabolic rate, rather than potential component traits will help explain relative performance levels in the field environments, e.g. if nutrition level is improved by utilizing improved grasses, legumes, or processed by-products.

Predicting the Results of Crossbreeding

There are many situations where it is desired to combine two or more breeds into a synthetic population. These situations may arise due to changed consumer requirements, national policies, or as apart of genetic improvement programs. It commonly occurs when a local breed is to be 'improved' by crossing to an exotic breed, sometimes simultaneously with improvement to the environment. The question arises, if genotypes to be crossed have been characterized in a relative sense, what will be the performance of the crossbred progeny? Unfortunately, without the knowledge of a large number of genetic parameters, it is not possible to predict the amount of heterosis or hybrid vigour that will occur.

It is generally known that heterosis is higher for traits that are largely determined by non-additive gene action, e.g. reproductive traits. It is also generally accepted that greater heterosis is expected from crossing breeds that are more genetically different, i.e. greater heterosis is expected in crosses between *Bos indicus* and *Bos taurus* breeds or between *Bos taurus* breeds from Europe or West Africa than, say, in crosses between European *Bos taurus* . In this respect, since the West African Shorthorn and Longhorn were introduced into Africa over 200 years ago (Epstein 1971), they may be genetically more akin to the tropically adapted *Bos indicus* genotypes than to their ancestral relatives.

The expectation, assuming epistatic interactions are minor, is that half of the heterosis in the F_1 generation, i.e. that arising from dominance deviations, will be lost in the F_2 generation or in back crosses. There have been very few attempts in domestic animals to test this expectation since in practice it is difficult to obtain truly comparative data on F_1, F_2, and F_3 generations, unconfounded by environmental factors including genetic maternal effects. It is also necessary to have contemporary back crosses and parental genotypes if separate estimates of dominance and epistatic effects are to be obtained. This is rarely possible.

Some evidence from Rockhampton (Seebeck

Table 5. Calving percentages in Africander cross (AX), Brahman cross (BX), and Hereford-Shorthorn (HS) cows (Seebeck 1973).

Genotype	Generation	
	$F_1 \times F_1$	F_2 and F_3
AX	76.4 (521)[a]	76.8 (868)
BX	81.2 (449)	60.7 (798)
HS	70.1 (291)	67.1 (515)

a. Numbers of matings in parentheses.

Table 6. Least squares constants (expressed as a percentage of the overall mean) for body weights of heifers at birth, weaning, and 2 years of age for Africander cross (AX), Brahman cross (BX), and F2 progeny of the reciprocal crosses (AXBX and BXAX) (Seifert and Hetzel unpublished).

Genotype	Birth	Weaning (180 days)	2 years
AX	3.8	-10.5	-3.1
BX	-5.5	+4.1	-1.2
AXBX F2 BXAX	+1.7	+6.4	+4.3
Total No. of animals	1 771	1 107	579

1973) indicated that the calving rate for BX cows dropped dramatically from F_1 to F_2 while the fertility of F_1 and later generations of AX cows was not different (Table 5). Thus it appeared that there was no residual heterosis in the F_2 for the BX line while in the AX line, all heterosis was retained. In terms of growth, for which non-additive genetic variation is relatively small compared with reproductive traits, the reduction in the F_2 in 250 day body weight was 1.6% for AX and 3.9% for the BX line animals (Seifert and Kennedy 1972). Since systematic crossbreeding programs are likely to have limited application in the tropics and subtropics (Frisch and Vercoe 1982), it is the residual heterosis in interbred F_2 and subsequent generations that is critical. Recent crosses between the AX and BX lines are providing a better data set for this purpose, since the parental lines are available for contemporary comparison. Although only limited data are available on the F_2 progeny, for which maternal heterosis will be exhibited by the F_1 dams, there is evidence (Table 6) of appreciable residual heterosis in body weight at 2 years of age (Seifert and Hetzel unpublished). This is an interesting result because the data were collected in essentially the same environment as the untreated ('high-stress') grazing environment of Frisch and Vercoe (1984). In that study, the parental genotypes (B and HS) and the crossbred (BX) had been under selection for more than two generations. The authors concluded that the crossbred grew better than both parents only at the medium level of stress, inferring that the level of heterosis may be different over the three environments. In the high stress environment, the Brahman breed grew at the same rate from birth to 18 months of age as the BX group. However, in the AXBX study, the crosses grew about 5% faster to 2 years of age than the more adapted parent (BX). Thus, it may be concluded that the level of residual heterosis was higher in the AXBX cross.

It would appear that recombination losses may be less than expected, at least in Africander crosses, suggesting that favourable epistatic interactions are retained in the F_2 generation. If this phenomenon is widespread, greater benefits from lines derived from crossbred foundations are likely. On the other hand, evaluations of F_2 progeny and F_3 (for estimates free from maternal heterosis) progeny are needed to assess properly the value of the stabilized crossbred.

Concluding Remarks

Under the natural and modified environments at Rockhampton, significant G x E interactions have been demonstrated, and a model to explain their occurrences in terms of component traits has been developed. The range of environments has been extensive, and the genotypes used for the studies also represent extreme types in terms of their level of adaptation. Nevertheless together they have demonstrated principles of genotype evaluation that will be generally relevant. Although extremes in genotypes or environments are not essential for evaluation to be meaningful, genotypes must be evaluated for both production traits and component traits, in a range of environments that permit estimation of the resistance to each major environmental stress and any interactions that may exist between them.

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Progress in the Evaluation of Cattle Genotypes for Northwestern Australia

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THE Kimberley region of Western Australia was populated with Shorthorn cattle from Queensland and New South Wales in the 1880s. The descendants of these cattle, supplemented occasionally by 'improved' Shorthorns from the south of the State, have been largely influenced by natural rather than artificial selection. The resultant type known as 'Kimberley Shorthorn' appears to differ very little from other Shorthorn cattle, apart from being fairly hardy.

The Kimberley which lies between 14° and 19° S latitude and 125° and 130° E longitude, has a total area of about 320 000 km², and by definition is tropical. The months of May-August are dry and relatively cool (maxima and minima of around 32° C and 16° C). In the remaining months, maxima exceed 35° C and in October-November usually exceed 38° C.

Rainfall ranges from 1000 mm in the north-west coastal area to less than 250 mm on the southern perimeter, and is confined to the 4 months between November and January, although occasionally useful rains occur in October or March. The pattern of rainfall is generally more unreliable than in areas of similar mean precipitation elsewhere in northern Australia (Petheram and Kok 1983).

The evaporation rate is high, ranging from 2000 mm to 2500 mm per year and late in the dry season reaches 300 mm per month in inland areas. This high rate of evaporation combined with the sporadic nature of precipitation results in pasture species being in water stress for over half the wet season.

The harsh conditions of the Kimberley combined with the use of cattle genotypes, which are not well adapted to heat or to internal and external parasites, have resulted in a low cattle turnoff and long growing times. An obvious approach to these problems is to search for cattle genotypes that may be better adapted and more productive under such conditions.

American Brahman and Santa Gertrudis cattle have been introduced in some areas for this purpose, and their crosses appear to offer some advantages. In the wetter Queensland tropics, Frisch (1976) found that *Bos indicus* crosses were more heat tolerant and more resistant to ticks and to internal parasites. However, although these adaptive advantages result in faster growth rates, the F_2 and subsequent generations appear to have reduced fertility.

In attempting to find a more fertile *Bos indicus* alternative, scientists at CSIRO Belmont have shown that the inter-bred Africander x Hereford-Shorthorn has a fertility advantage over Brahman crosses and grows satisfactorily under their conditions (Seifert 1975b).

The opportunity arose to compare, in the drier Kimberley environment, Africander by Shorthorn and Brahman by Shorthorn crosses with the traditional straight Shorthorn.

Materials and Methods

Ord River Station

The area on which this study takes place lies across the Western Australian/Northern Territory border about 200 km south of Kununurra, and is traversed by several major rivers, including the Ord and its tributaries. The country is undulating and consists of plum-coloured soils of high alkalinity (pH 8.8-9.0) on Cambrian sediments. The annual rainfall of about 450 mm is very unreliable.

The soils are extremely unstable, and uncontrolled use in the past has resulted in massive erosion following the removal of native perennial vegetation. A cultivation-based rehabilitation program has permitted regeneration of much of the catchment. The present pastures consist mainly of Birdwood grass (*Cenchrus setiger*) on the areas where the cattle are run. Some native species such as Limestone grass (*Enneapogon* sp), Ribbon grass (*Chrysopogon* spp) and White grass (*Sehema* sp) have colonized areas not yet established with Birdwood grass.

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Stocking rates

The various genotypes are run together except at mating time and are stocked according to the fairly variable condition of the particular paddocks. These rates range in the extreme between 12 and 30 ha per cow, with most paddocks about 15 ha per cow. Steers are run in larger paddocks at around 40 ha/beast.

Cattle

Six genotype groups of 100 cows each are being built up for comparison:

	Number in 1983
Straight Shorthorn (S)	107
Straight Brahman (B)	106
F_1 Brahman x Shorthorn (F_1 BS)	103
F_2 Brahman x Shorthorn (F_2 BS)	64
F_1 Africander x Shorthorn (F_1 AS)	87
F_2 Africander x Shorthorn (F_2 BS)	32
S mated to B	64
S mated to A	83

Replacement heifers are introduced to each group at 20 per year and are mated first at 15 months of age. Although fertility to this mating is poor, it is felt that it is more satisfactory than leaving the possibility of chance matings as the females mature.

Management

Cows are joined with bulls for 2 months from March 1st each year. In each genotype group of about 100 females, 4 bulls are group mated.

At birth, calves are ear tagged and the identity of their dams is recorded. Additionally in 1980, birth weights were recorded. Calves are branded when cows are mustered at the end of mating, and both cow and calf weights are recorded at this time. Weaning takes place at the end of July when cow and calf weights are again recorded.

Cows are pregnancy tested in November and weights are recorded. Steers are bulked at weaning and are grown out in paddocks that typify normal industry practice. Half of the steers are selected at random for slaughter at 2.5 years of age and the remainder at 3.5 years of age. Each year they are weighed in May and in November until slaughtered when carcass weight and back-fat thickness at the 12/13 rib are also recorded.

Analysis

Data were analysed by ordinary least squares methods (Harvey 1975). There are, however, insufficient data as yet to warrant analysis of fertility information.

Results

In 1980, birth weights were measured in the types available at the time and are presented in Table 1. The model contained the effects of breed, sex, and dam age.

Table 1. Main effects on birth weight, 1980.

Main Effect	Least squares mean	Standard error	N
Breed			
S*	30.1 kg	0.61	78
B	31.1 kg	0.78	40
F_1 BS	33.2 kg	0.71	57
F_1 AS	30.6 kg	0.88	24

S = Shorthorn, B = Brahman, A = Africander

*Effect of breed highly significant ($P < 0.001$).

In 1980, the effects of breed, sex, and dam age were all significant influences on birth weight, whereas breed and sex were the major effects on weaning weight, and growth rate to weaning.

No birth weights were taken subsequent to 1980. The remaining analyses on weaning weight, birth day, and growth rate to weaning had year of birth added to the model. All main effects were significant for these three variables with the exception of the effect of age of dam on day of birth. These are presented in Table 2.

Growth data for the steers are presented in Table 3. The analytical model included the effects of breed, year, and breed x year. The latter effect was not significant in this data set and is not further considered. Because of the early stage of the trial these data are not complete. Data are first presented for weight gains during the first wet season, the first dry season, and actual weights at 15 months and 22 months.

Data from the slaughter of steers at 2.5 years of age are available for genotypes from two birth years and for slaughter at 3.5 years of age for only three genotypes and one year. These data are presented in Tables 4 and 5, respectively.

Table 2. Main effects on growth rate to weaning, actual weaning weight, and day born. Least squares means (and standard errors) are shown.

Main effect	Day born	Growth rate to weaning (kg/d)	Actual weaning wt. (kg)	N
Breed: S	23.2 (1.3)	0.50 (0.01)	129.6 (1.8)	176
B	30.9 (1.7)	0.65 (0.01)	151.1 (2.3)	100
F_1 BS	29.2 (1.9)	0.54 (0.01)	137.0 (2.6)	85
F_1 AS	28.3 (2.0)	0.51 (0.01)	128.8 (2.7)	76
F_2 BS	24.4 (1.5)	0.63 (0.01)	155.4 (2.1)	120
F_2 AS	29.5 (3.5)	0.58 (0.02)	141.5 (4.7)	22
P	<0.001	<0.001	<0.001	
Sex M	27.6 (1.5)	0.59 (0.01)	144.9 (2.0)	291
F	26.1 (1.4)	0.55 (0.01)	137.1 (2.0)	295
P	N.S.	<0.001	<0.001	
Age of Dam 2	33.5 (2.9)	0.45 (0.02)	114.5 (3.9)	34
3	22.5 (2.1)	0.57 (0.01)	144.4 (2.8)	74
4	24.6 (1.8)	0.62 (0.01)	153.1 (2.4)	88
5	27.0 (1.2)	0.62 (0.01)	152.0 (1.6)	390
P	<0.01	<0.001	<0.001	
Year 1980	36.5 (1.8)	0.56 (0.01)	132.5 (2.4)	199
1981	20.6 (1.7)	0.54 (0.01)	141.0 (2.3)	169
1982	23.6 (1.4)	0.59 (0.01)	149.6 (1.9)	218
P	<0.001	<0.001	<0.001	

S = Shorthorn, B = Brahman, A = Africander.

The amount of cow fertility data is as yet insufficient to warrant a complete analysis and the following raw data are presented as a guide only. Table 6 presents raw fertility data from the first three matings excluding 15 month heifer matings.

Discussion

Because of the early stage of the experiment, it would be unwise to make too much of the results to date. This is so because only 3 years are represented and the number of sires used in each group is as yet small. A number of points are worth making, at least tentatively.

1. The breeds appear to differ only slightly in birth weight, and, in the only year measured, the residual correlation of birth weight and weaning weight appeared to be of the part-whole type, since the correlation between birth weight and pre-weaning gain was near zero.

2. The Africander crosses appear to be little better than Shorthorns in weaning weight in the years

Table 3. Main effects on 15 month and 22 month weights and growth during wet and dry seasons of steers. Least squares means (and standard errors) are presented in kg.

Main effect	15 month wt.	Dry gain	22 month wt.	Wet gain	N
Breed					
S	266.7 (5.2)	40.0 (2.5)	306.7 (5.8)	113.7 (2.9)	41
B	314.8 (7.5)	35.8 (3.6)	350.6 (8.3)	132.6 (8.3)	23
F_1 BS	316.9 (9.0)	50.4 (4.4)	367.3 (10.0)	144.1 (5.1)	15
F_2 BS	316.4 (7.0)	37.6 (3.4)	354.0 (7.8)	130.8 (4.0)	33
P	<0.001	N.S.	<0.001	<0.001	
Year					
1980	277.0 (6.4)	14.2 (4.0)	291.2 (7.1)	116.0 (4.0)	29
1981	309.9 (6.5)	64.3 (3.1)	374.3 (7.1)	141.7 (3.7)	27
1982	324.2 (5.1)	44.3 (2.5)	368.5 (5.6)	133.2 (2.9)	56
P	<0.001	<0.001	<0.001	<0.001	

S = Shorthorn, B = Brahman.

Table 4. The effects of breed and year of birth on steer slaughter characteristics at 2.5 years - least squares means (standard errors).

Main effect	Live wt. (kg)	Carcass wt. (kg)	Fat thickness (mm)	N
Breed S	416.9 (7.4)	228.8 (6.4)	5.3 (0.8)	21
B	465.4 (10.9)	243.4 (9.5)	6.8 (1.1)	10
F_1 BS	481.5 (9.2)	253.1 (8.1)	7.9 (1.0)	15
F_2 BS	487.0 (10.6)	250.6 (9.3)	5.0 (1.1)	10
P	<0.001	N.S.	N.S.	
Year 1980	444.8 (6.8)	235.0 (5.9)	5.4 (0.7)	29
1981	480.6 (6.8)	253.0 (5.9)	7.1 (0.7)	27
P	<0.001	<0.05	N.S.	

S = Shorthorn, B = Brahman.

Table 5. The effects of breed on the slaughter characteristics at 3.5 years — least squares means (standard errors).

Main effect	Live wt. (kg)	Carcass wt. (kg)	Fat thickness (mm)	N
Breed S	550.6 (13.3)	281.7 (6.7)	9.6 (1.2)	13
B	584.0 (33.9)	320.0 (17.0)	10.0 (3.2)	2
F_1 BS	609.8 (13.8)	319.7 (7.0)	9.2 (1.3)	12
P	<0.05	<0.01	N.S.	

S = Shorthorn, B = Brahman.

Table 6. Actual calving percentages arranged by breed.

Breed	Calving percentage 1980 Mating %	N	1981 Mating %	N	1982 Mating %	N	Overall	
S	45	(298)	59	(272)	63	(254)	55	(824)
B	36	(105)	40	(107)	68	(106)	48	(318)
F_1 BS	58	(93)	63	(109)	54	(103)	58	(305)
F_1 AS	47	(45)	58	(44)	88	(87)	70	(176)
F_2 BS	—	(6)	—	(17)	47	(64)		
F_2 AS	—	(18)	—	(18)	71	(32)		

S = Shorthorn, B = Brahman, A = Africander.

studied, with the Brahman and Brahman crosses superior by about 10-20%.

3. With the limited data so far available the Brahmans and crosses appear to grow faster in both wet and dry seasons than the Shorthorns. This resulted in carcass weights about 20 kg higher at 2.5 years of age and about 40 kg higher at 3.5 years of age.

4. Although the fertility data are sparse as yet, the F_2 Brahman Shorthorn crosses appear to suffer a penalty compared with the Shorthorn, with the Africander crosses showing a marked advantage. With the small numbers, both bull effects and year effects could be quite large.

Even the relatively limited aims of this experiment are very costly to achieve and will leave us with many important unanswered questions. While this trial will provide data on productivity of a small range of likely genotypes under the very variable and dry tropics of northwestern Australia, we will need, for rational decision making, information on other alternative genotypes, heterosis effects, and particularly specific effects of genotype-environmental interactions. Provision of such information will certainly be a cooperative effort.

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Genotype Evaluation of Bovid Production in the Monsoon Zone of the Northern Territory

G.W.M. Kirby*

IN the Northern Territory (N.T.) the environment presents severe limitations to large ruminant production. The climate is arid in the south and gradually changes to wet monsoon on the northern coast. Within the total area of 1.332 million km², 58% is in rural holdings and 80% lies in the tropics. The area north of the town of Tennant Creek is subject to the influences of the north-west monsoon.

In this monsoon zone the annual rainfall is 350 mm in the south and steadily increases to 1504 mm at Darwin. The corresponding period of pasture growth is 3 months increasing to 6 months at Darwin. Temperatures are relatively high with the degree of (human) discomfort increasing with the higher relative humidity to the north where there are relatively small diurnal variations. Solar radiation in the monsoon zone is relatively higher in the dry season thus offsetting the beneficial effects of lower temperatures and humidities.

In summary the climate constraints can be particularly severe as Australia's upper extremes of wind, temperature, heat waves, total annual rainfall, annual rainfall variability, rainfall intensity, rainfall seasonality, and average daily radiation all occur within this zone.

The major soil groups in the pastoral areas are the shallow stony soils, cracking clays, and massive sesquioxides. Collectively, the main soil limitations are shallow depth, low water-storage capacity, coarse surface, high erodibility, and very low organic matter, nitrogen, and phosphorus levels. These features, with the summer dominant rainfall, severely limit the growing season, quantity, and quality of pasture growth.

The distribution of major pasture communities (Mitchell grasses, short grasses with forbs, chenopods, spinifex, *Aristida* sp, tall tropical grasses, and the grasses of flooded and coastal country) depends primarily upon rainfall and soil patterns. In general, density is relatively low. Quality significantly decreases from south to north. Typically, quality is good (> 1.2% N) early in the growing season but steadily decreases into the dry season (often down to 0.17% N). Thus both pasture quality and density represent stress factors to the ruminant during much of the year. Compounding this problem are the large areas of pasture burnt during each dry season.

Most of the common internal parasites have been recorded. However, they appear to be economically important only in limited situations. The main external parasite is the cattle tick (*Boophilus microplus*). Its effect on cattle is limited by the long dry season and low stock density. However, it does become very important in situations of high stock concentration, poor condition, and stock of low tick resistance.

Infectious diseases and toxic plants can be important stressors at some times and places. Feral animals are significant as grazing competitors (e.g. donkeys) and predators (e.g. pigs, dingoes) especially on young stock.

Grazing animals have to walk considerable distances daily between forage areas and watering points. While it is considered desirable to have grazing areas within 8 km of a watering point these distances impose stresses and therefore limit productivity.

The husbandry practices employed in this zone, especially those associated with harvesting (vehicle/helicopter mustering) and long distance transport impose further limitations to animal production.

Industry Productivity

The two large ruminants of economic importance are buffaloes and cattle. In 1980-81 N.T. cattle earnt $67.8m and buffaloes $7.1m. The total cattle population is approximately 1.6m distributed between the Darwin and Gulf (18.1%), Victoria River (27.5%), Barkly Tablelands (25.7%), and Alice Springs (28.7%) districts. Buffaloes are located north of Katherine with the main concentrations on the coastal plains. The buffalo population (largely feral) was estimated at 282 000 in 1981 (Graham *et al.* 1982)

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but has since declined with heavy harvesting.

All biological measures indicate low levels of cattle productivity in the monsoon zone relative to temperate and some other tropical areas. Growth rates, weaning weights, turnoff weight for age, cow weights, pregnancy rates, calving and weaning rates, juvenile and adult survival rates are all substantially depressed. Turnoff has increased from approximately 12% to 18% over the last 30 years, approximately one third the level of the majority of the Australian herd. Turnoff rate increases from the coast southwards.

The productivity pattern can be illustrated using a BRIN (BReeders as an INvestment) model, which was developed by the Bureau of Agricultural Economics and subsequently adapted to N.T. conditions by the author. As an example some production characteristics of a 'reference herd' (approximating to an average herd) in the Victoria River District (VRD) are:

- Overall cow mortality rate: 8.5%
- Weaner mortality rate: 10%
- Male mortality rate: 4-6%
- Overall branding rate: 54%
- Average age of male turnoff: 3.84 yrs
- Average weight of male turnoff: 396 kg
- Herd size: 20 795 head
- Net cash income: $138 820
- Turnoff: 14.1%
  : 61 kg live weight per dry cow equivalent carried.

Considerable variation in the production pattern exists within each district and between districts and years. However, depressed productivity remains a common feature.

Industry Development

Cattle property development options include cost minimization (e.g. cheaper fencing), increasing carrying capacity (with improved pastures and rangeland management) and improved herd productivity, which includes genetic improvement. Genetic improvement requires only a relatively small private capital investment and it has long-term benefits.

The potential benefits of genetic improvement using the VRD (predominantly Shorthorn) herd model above is shown in Table 1. The 25% increase in herd production derives from increases of 5% in branding rate, 3% in cow survival rate, 2% in weaner and male survival rates, and 5% in turnoff live weights. The 6.7% production increase derives from a 1% increase in branding rate, survival rate, and live weight. All are achievable objectives.

In the monsoon zone the cattle producers have gradually been introducing *Bos indicus* cattle since 1960 into the Shorthorn herd. The main *B. indicus* breeds are Brahman, Santa Gertrudis, Droughtmaster, and Brafords. More limited introductions have been made of Africanders, Belmont Red, and large European breeds. Pastoral district surveys indicate a general intention by pastoralists to introduce more *B. indicus* but considerably more progress has yet to be made.

Breed and Species Research

The genotype evaluation projects have aimed to improve the level of productivity, adaptation to the environment, and farm income. The projects have included studies on breeds, genetic parameters, and selection — Coastal Plains Research Station (CPRS); breeds — Katherine Experiment Farm (KEF); breeds — Victoria River Research Station (VRRS); selection — VRRS; sire breeds — Upper Adelaide River Research Station (UARRS); buffalo comparative performance — CPRS and other localities; banteng comparative performance and crossbreeding — CPRS; dairy cattle — near Darwin; and adaptation studies — various localities.

Beef Cattle

(1) *Coastal Plains Research Station Cattle Herd:* This first breed evaluation project was initiated in 1962 and it evolved into the following design using single-sire matings and full pedigree recordings:

Sires	Dams	Period	Design
Shorthorn (SH)	SH	1962-78	Control group
Santa Gertrudis (SG)	SGX and SH	1963-75	Grading-up, Selection
Brahman (BR)	BRX and SH	1964-78	Grading-up, Selection
Sahiwal X (SAHX)	SAHX and SH	1967-70	Grading-up
Africander X (AFRX)	AFRX and SH	1969-78	Grading-up
Brahman X (BRX)	BRX	1976-78	Control group

Data collected during 1962-70 were sequentially analysed within and between years, and adjusted for the more important sources of non-breed variation (Kirby 1977a). Subsequently the individual and maternal genetic components (additive, heterosis, and epistasis) of eight production traits were estimated in SG and BR breeds relative to SH (Kirby 1977b).

Table 1. Benefit-cost ratio relative to genotype investment and productivity gains in VRD reference herd (RH).

Productivity gain (%)	Genotype investment ($/breeder mated)						
	2.5	3.5	5	7.5	10	15	22.5
O (RH)	1.0						
+ 6		4.9	1.9	1.0			
+ 25		19.9	7.9	3.9	2.6	1.6	1.0

Mean herd productivity was low: Birth weight (BW) 27.7 kg, weaning weight (WW) 116.2 kg, post-weaning weight (PW) 212.5 kg, cow weights 331-343 kg, fertility (pregnancy rate) 49%, foetal and calf losses to weaning 23%, post-weaning heifer mortality 13%, and cow mortality 7%.

There was a general lack of importance of maternal genotype effects for adjusted (adj.) BW (BRX only), adj. WW and adj. dam weight at weaning (DWW). This suggests that there were little breed-of-dam differences in providing a prenatal environment or postnatal milk production. Increasing the BR content of a calf improved (20.4%) its dam's adjusted weight at weaning.

Heterosis and recombination epistasis were generally more important than additive genotype in the SG breed contribution and vice versa in the BR breed. Exceptions were major heterosis effects (+15%) in the BRX post-weaning period, and additive effects in the SGX pre-weaning period (+17%) and cow weight change during the February-June period (8-10%).

The additive breed genetic effects for growth were maximum during the pre-weaning period in both SG (+17%) and BR (+31%) breeds. Additive relative to heterotic SG and BR breed differences in cow weight change decreased from maximum values in February-June period to minimum values in the November-January periods. The higher additive breed effects were generally associated with cow weight gain and maintenance periods.

In general, calf growth rates were ranked as BRX > SGX > SH. Pre-weaning growth rates of AFRX and SAHX calves were much higher than for SH calves but still lower than for SGX and BRX calves, except for calves that also had some BR genes. The AFRX and SAHX cow weight changes were similar to SGX and BRX cows, and greater than SH cows.

Herd fertility levels were partitioned into breed of bull, adaptation of cow breed, and cow breed threshold level for conception. Bull fertility ranked as BR (+12%) > SG (-12%) < SH but this relativity was extremely variable. Adaptation of cow breed ranked as BRX (+33%) > SGX (+26%) V SH. For cow breed threshold level (i.e. pregnancy rate independent of body condition, weight, and weight change effects) SG breed exhibited some heterosis (+7.4%) relative to SH, and the BR breed had an additive genetic effect of -35%. In the crossbred herds used, overall herd fertility differences expected were +11% for SGX and +26% for BRX relative to a SH herd.

There was a definite survival advantage of all Zebu cross cows over SH cows by up to 7%.

It was not possible to evaluate breed differences in terms of the potential genetic gain because of high standard errors of heritability and genetic correlations.

Although no analyses have been carried out on post-1970 data, the data now assembled from this herd represent a valuable source of information on breeds and selection effects in a wet monsoon environment.

Body condition, milk-use efficiency, cattle ticks, internal parasites, heat stress, water turnover, body solids, behavioural and temperament patterns were examined. Experimental limitations existed but breed differences clearly existed for tick resistance and heat tolerance.

(2) *Katherine Experiment Farm Cattle Herd:* In the period 1965-70, BR and SG bulls were mated to SH cows, and the results are shown in Table 2. These results conform to the CPRS pattern above.

Table 2. KEF representative breed comparison data (unadjusted).

	S	F_1(SGxS)	F_1(BxS)
Birth weight (kg)	32.1	30.8	33.8
Pre-weaning gain (kg/day)	0.66	0.83	0.82
Weaning weight (kg)	168	198	205
Post-weaning gain (kg/day)	0.20	0.34	0.45
1½ yr weight (kg)	197	268	308
2½ yr weight (kg)	372	427	512

SG = Santa Gertrudis, S = Shorthorn, B = Brahman.

(3) *Victoria River Research Station Steer Project:* In 1973-75 three groups, one commencing each year, of ½BR½SH (not F_1) and SH steers, were evaluated for post-weaning growth to 3½ years of age, body condition, tick burden, and dressing percentage.

Post-weaning live weight of the BRX increased with age relative to SH live weight by up to 50-100 kg (approx. 14-32%) at approximately 2 yrs of age. Subsequently this difference decreased by 20-25 kg by 3½ years of age.

One group, slaughtered in June, dressed out at 59.1% for BRX cross bullocks and 56.4% for SH bullocks. This differences probably relates to observation that the BRX steers were consistently in better condition with an average subjective score 0.83 units (scale 2-9) above the SH.

For two groups over 3 years, the BRX cross steers carried 7.6 ticks per side and the SH steers 24 ticks/side.

(4) *Victoria River Research Station Selection Herd:* A popular attitude is that the N.T. Shorthorn has become well adapted to its environment and it merits further attention to protect and enhance its genetic potential. During the 1970s on VRRS, a SH herd was under selection pressure for pre-weaning and post-weaning growth rate.

Although the project was terminated, adequate information (from the unanalysed data) may be available to indicate the likely response to selection within the SH breed in the N.T.

(5) *Upper Adelaide River Research Station Sire Breeds:* The effect of terminal sire breeds was recorded on bull calves produced by AI out of ⅝ (approx) BR⅜SH cows (Wesley Smith, pers. comm., 1984). Charolais (CH), SH and BR sired calves weighed 132, 130 and 121 kg respectively, at weaning. Subsequently the BR sired progeny increased live weight to 30-32 kg in excess of the CH and SH sired calves at 2 yrs of age. Body condition was best in BR sired progeny and worst in the SH sired progeny. Tick burdens were highest (13.0/side) in CH sired calves and lowest (3.5/side) in BR sired calves.

Buffalo

The productivity and management of the water buffalo (*Bubalus bubalis*) in Australia has recently been reviewed by Ford (1982) who undertook the major studies of comparing the herd productivity of buffaloes with ¾ BR ¼ SH cattle.

With renewed interest in controlled buffalo raising the research herd was established at CPRS in 1970 to gather base line data on the productivity of domesticated buffaloes in their adopted habitat and to assess their performance against local BRX cattle. The animals were run on native pastures to simulate the nutritional conditions to which the feral herds appeared to be well adapted, and under which many domesticated herds would probably be run in the future.

Species evaluations have included nutritional and climatic physiology, mortality, longevity, reproductive ability, weight and body condition changes under various management conditions, carcass and meat characteristics, and husbandry methods.

Adult live weights of the cattle and buffalo cows stabilized at about 7 years and 8-9 years of age, at weights of 356 kg and 459 kg, respectively. Maintenance requirement differences would be proportionately less because buffalo requirement per unit live weight is lower (Vercoe and Frisch 1977).

The average adult body condition score was 7.4 for buffaloes and 6.3 for cattle (scale 2-9). Body condition and live weight were depressed in both species in the dry season. However, the cattle suffered a greater average seasonal reduction in body condition.

Poor dry-season pasture quality, exacerbated by occasional dry season calving and lactation, was responsible for the deaths of almost one half of the cattle in the 1970-78 period. None of the buffalo breeder deaths were due to poor nutrition during the dry season, despite the fact that most buffalo lactations occurred then.

The buffaloes had significantly shorter calving intervals than the cattle despite a gestation period longer by approx. 40 days. These intervals of 467 and 571 days, represent calculated average annual calving rates of 78% for the buffaloes, and 64% for the cattle. Average buffalo heifer age at first calving was 39 months. The buffalo cows were still calving regularly at approximately 15 years of age.

The shorter calving intervals of the buffaloes reflect a superior ability to reconceive while still lactating. Only 10% of the cattle conceptions occurred before their calves were weaned (at an average age of 192 days), so calving was generally limited to two calves in 3 years. Occasionally Brahman x Shorthorn cows raised calves in 3 consecutive years, but none did so in 4 or more years. By contrast, 77% of buffalo conceptions occurred in the first 192 days of lactation, and calving in 4 or 5 consecutive years was common. Twelve of the original 33 buffalo cows raised a calf in 6 years out of 7, and four of these did so in 6 consecutive years.

Buffalo calving peaked in March, with over 90% of buffalo calves being born in the December-June period. Cattle calving was distributed more evenly throughout the year.

Foetal and calf losses to weaning comprised 8% and 7%, respectively, of buffalo and cattle pregnancies.

There was no difference in pre-weaning (to 6 mths) live weight gain, either between sexes of calf, or between buffaloes (485 g/day) and cattle (504 g/day).

Six post-weaning growth rate comparisons between buffaloes and BR X SH cattle grazing medium quality pastures have been reported by Ford (1978) and one by Robertson *et al.* (1982). Each of the comparisons involved 5-10 animals of each genus run together until 2-3 years of age, with two groups being continued until 4½ years of age.

Comparisons of 15 out of 26 periods of weight gain (i.e. wet season), or weight loss (dry season), indicated no overall differences in weight changes between buffaloes and cattle. Sex and castration did not affect live weight gain in buffaloes.

On a concentrate ration, feed intake and live weight gain (1.14 kg/day) of 2½ year old buffalo steers were less than BRX steers but the feed conversion rate (6.6 kg DM/kg gain) was similar.

Meat losses from carcass condemnations due to bruising are very limited in buffaloes, despite often adverse ante-mortem treatment that would cause extensive condemnation in cattle (Pearson 1981). This effect is generally attributed to the protection afforded by the relatively thick hide of the buffalo.

The dressing percentages of buffalo and BR x SH steers raised together and slaughtered at similar empty live weights (447 kg and 437 kg, resp.) were 50.9% and 53.9%, respectively (Robertson *et al.* 1983).

Buffalo and BR x SH steers raised together and slaughtered at similar live weights (429 kg and 439 kg, respectively) had carcass fat levels of 19.0% and 25.9%, respectively (J. Robertson and D. Charles, pers. comm., 1981). The buffalo has a lower ratio of subcutaneous to intermuscular fat and a higher proportion of kidney and pelvic channel fat than cattle (Charles and Johnson 1972). In addition, the fat is firm in texture and white in colour. Castration appears to increase carcass fat percentage in buffaloes, but not to the same extent as in cattle. The usually lower proportion of fat in buffalo compared with cattle carcasses is therefore reflected in a greater proportion of muscle.

Comparative meat studies (Robertson *et al.* 1983) indicate that overall buffalo meat was less acceptable than that from BRX cattle of similar age and history. Buffalo meat was darker and tougher in older animals with greater cooking losses. Tenderness and juiciness were improved in both species by tender-stretching.

Banteng (Bali Cattle)

The banteng (*Bos javanicus*) is a bovine with a cattle-like appearance but it is an entirely different species from either European cattle (*Bos taurus*) or Zebus (*Bos indicus*).

N.T. interest was renewed in them is the early 1960s because they were unique, thrived under hot and humid conditions, maintained good body condition throughout the year, appeared to be tick resistant, and offered the prospect for crossbreeding improvement of commercial cattle.

From 1961-79 several expeditions have captured bantengs and transferred them from Cobourg Peninsula to CPRS where there has been a program of redomestication, species evaluation, and crossbreeding research and development. This work, has been reviewed by Kirby (1979).

Banteng calves were small and weighed about 17 kg at birth, compared with 30 kg for the BR x SH calves; they grew very slowly when the herd was run on pasture. Growth rates during the first 6 months (0.22-0.27 kg/day) were only about 30% of those of the BR x SH calves (0.68 -0.82 kg/day). The milk production and consumption of banteng cows was only 25% and 40% respectively, of that of BR x SH cows. However, no differences were evident in the conversion efficiency of milk to body solids or live weight.

As growth continues, banteng live weight remains low compared with BR x SH live weight. Comparable measurements include a live weight gain on improved pastures of 65 kg and 121 kg for the first 12 months of age, and mature live weights of 298 kg and 409 kg for banteng and BR x SH cows, respectively. However, relative to mature live weight, the live weight advantage of the BR x SH yearling is reduced to approximately 8%. The slower growth and smaller mature size of bantengs do not necessarily imply a lower efficiency of feed use. Bantengs at all ages have a better ability than BR x SH cattle to maintain body weight (Moran 1973a) and body condition even when pasture quality becomes poor or when cows are lactating.

Bantengs normally have very high conception rates despite the monsoon-induced environmental stresses. They can regularly achieve 90-100% conception compared with the expected 60-70% for the contemporary BR x SH cattle.

Because of the slow growth rates in this environment, the banteng heifers do not normally conceive under 36 months of age, compared with approximately 24 months for the BR x SH contemporaries. Unfortunately, net reproduction rates in bantengs in this environment are low, due to the high mortality — up to 80% — of the young stock (birth to 16 months), compared with 0-10% for BR x SH cattle. The basic causes of this high rate of loss are the low milk production and adverse behavioural patterns of bantengs under extensive herd management. Bantengs and young stock are very timid and can be easily upset. The dam-calf bond is much weaker than in cattle.

Compared with cattle breeds the banteng has a much higher proportion of its muscle weight in the hindlimb and around the spinal column and less muscle weight in the forequarter and abdominal wall (Berg and Butterfield 1976). The fat of the bantengs tends to be yellow in colour and is softer than in cattle. Fat deposition is minimal but adequate for cooking.

Crossbreeding began in 1967 and, following encouraging results, a program to evaluate various banteng x BR x SH crosses systematically, and ultimately to produce a synthetic breed, was started in 1970.

Pregnancy rates in F_1 cows (70-90%) were higher than in BR x SH cows (60-70%). The F_1 calves at birth were very strong and vigorous and, with the relatively good milking ability of the BR x SH dams, had very high survival rates that continued throughout life. The pre-weaning and post-weaning growth rates of F_1 and BR x SH animals are similar. The F_1 body condition scores are higher than those of the BR x SH. With backcrossing to both banteng and BR x SH bulls, all productivity measures decline though at varying rates.

Two problems that arose were F_1 bull sterility and F_1 management difficulties because they combined strength and vigour with the nervous temperament of the banteng parent. In the ¼ banteng the temperament problem largely disappears. Bull infertility tends to persist in first backcrosses. However in 1980 the first *inter se* calves were born, sired by one ¼ banteng and one ¾ banteng bulls. These *inter se* female calves have subsequently (1983-84 wet season) produced calves. These animals have the potential to form the foundation of a new synthetic breed in Australia. However the future of this program is uncertain.

Dairy Cattle

A small study commenced in 1980 to compare the performance of tropical (Australian Friesian-Sahiwal, Australian Milking Zebu) and temperate (Friesian, other *Bos taurus* breeds) dairy cattle near Darwin. The results may be relevant in indicating the genetic potential for increasing mothering ability in beef cattle. Preliminary unadjusted data indicate that non-Friesian *B. taurus* milk production per lactation is lower (30%) than that of the other three breeds.

Adaptation Studies

Norton *et al.* (1979) concluded that, despite differences between species (BRX, buffalo, banteng, SH) in urea synthesis and degradation, there was little indication that these differences constituted a significant nitrogen conservation mechanism in any one species. In the same species Moran *et al.* (1979) found that there were few differences between the species in their ability to digest and utilize low quality roughage when comparisons are made between animals of similar live weight and feed intake.

In the wet season, body water turnover rates were highest in buffaloes, with SH higher than SGX, BR cross, and bantengs (Siebert and Macfarlane 1969). In the dry season the rates were highest in buffaloes and lowest in bantengs.

The comparative nutrition studies have not yet identified any distinctive physiological advantages in bantengs. Obviously more work is needed to understand the ability of buffaloes and bantengs to maintain weight, good body condition, and to thrive so well on poor quality pastures.

In heat tolerance studies by Moran (1973b) the buffaloes were judged to be least heat tolerant in both stationary and exercise trials, with the SH showing the second highest rectal temperatures as a result of imposed heat stress. The heat tolerance of BRX and bantengs differed little in stationary trials, but the bantengs were more stressed by forced exercise. Cutaneous evaporation rates were higher in banteng than BRX and lowest in buffaloes under heat stress.

In a cattle tick study (Gee *et al.* 1971), the post-1½ year old body weight increases of BRX steers were significantly greater than SH steers, and the SH steers carried significantly more ticks. The cattle ticks, during a period (March-September) of high infestation (over 20 ticks per side), had a greater retarding effect on the growth of SH (-30 kg) than BRX (-19 kg). Two SH steers died from the tick burden.

Industry Application

The choice of genotypes and mating systems by producers must be very closely related to their particular environment and management system.

The above research projects were all run between 1961 and 1980. No new projects have since been commenced. However, a considerable amount of new information is contained in the accumulated data records (of which a large portion is unanalysed), especially from the three CPRS herds including cattle breeds, buffaloes, and bantengs.

Application of research to the cattle industry will be in the form of extension advice on breeds, breed crossing, grading up, breed replacement, development of synthetic breeds, selection, and culling especially in station bull breeding units.

In buffalo areas the research information enables a more objective choice to be made between buffalo and cattle raising enterprises. In addition, basic data will be provided for management and herd improvement purposes.

Purebred bantengs (Bali cattle) should be actively conserved to ensure provision of germplasm for future genetic exploitation for animal production. This could take the form of either terminal sire crossing, using banteng bulls, or the development of new synthetic breeds, of which some animals have been produced.

International Aspects

There have been no cooperative breed evaluation research projects between the N.T. Department of Primary Production and overseas countries. Numerous professional contacts have been effected over the years and liaison has occurred on all aspects of bovid production in the tropics. Resources exist in DPP to enable integration into future international projects on large ruminant genotype evaluations.

The N.T. research results should have a widespread applicability through much of the grazing lands of tropical Asia and Africa, especially in (a) areas with severe climatic and nutritional stressors, (b) rangelands (where seasonal control is limited), and (c) environments with a distinct wet season/dry season (monsoon) pattern.

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Evaluation of Beef Cattle Genotypes by the Queensland Department of Primary Industries

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THIS paper briefly describes the nature of the beef cattle industry in Queensland, the scope and type of research conducted by the Queensland Department of Primary Industries, the results of past work and the aims of current research programs, and finally, the relevance of this work to South-east Asia and Africa.

Beef Production in Queensland

The genotype evaluations and comparisons that we have made and are now doing need to be seen in the context of two important features that are characteristic of the Queensland beef industry.

Firstly, Queensland is essentially tropical or subtropical and much of the technology that has been developed in temperate countries is not applicable to our situation. The southern inland part of Queensland has climatic features that make it intermediate between the subtropics and the temperate zones. Beef production in this part of Queensland is similar to that in the temperate Australian states.

The second feature of the beef industry is its very extensive nature. Low fertility soils, low and erratic rainfall, and low beef prices have resulted in a preponderance of large properties running many hundreds of cattle with a very small labour force. A survey in 1976 (Hall and Acutt 1978) of 600 holdings showed an average of 1400 head per holding with only one full time employee to augment the owner/manager and his family. Low carrying capacity (from 1 head per 3 ha on good country and down to 1 per 50 ha in the worst) means very high costs per head for fencing and other development. As a consequence of this feature of the industry, labour intensive technology is generally irrelevant and inapplicable. Research has had to take cognizance of this.

Before 1950 all beef cattle were derived from British stock, mainly Hereford and Shorthorn, with a few Devon and Angus herds. Until the mid-50s it was generally believed that genetic merit lay only in the south — or in Britain. Very few producers questioned this dictum, and the possibility that animals selected in temperate climates might not be the best for the tropics was not entertained. However, in 1933 a few pioneers did query established wisdom, and imported 18 Brahman cattle from the USA. Brahmans were regularly imported until 1958 when all imports were banned as a disease security measure. A total of 7 Africanders (from the USA), 10 Sahiwals and 5 Red Sindhis (from India) were also imported before the ban (Daly 1981). Most producers, research scientists, and extension officers were slow to see the merits of breeds that had evolved in the tropics because they had no information on which to judge them. As data on their productivity became available and as scientists gained a better understanding of the role of *Bos indicus* for environmental adaptation, the *Bos indicus* crosses gradually took over from the *Bos taurus* breeds, as shown in Table 1.

Today these *Bos indicus*/*Bos taurus* crosses predominate in Queensland, except on the Darling Downs and in the south-west region, which are tick free and generally more temperate in climate.

From the Taurus/Indicus crosses there have become established a number of recognized tropically adapted 'breeds'. These breeds and the nominal components in eighths of the foundation breeds are:

Santa Gertrudis — Brahman^3 x Shorthorn^5 (Imported from USA)
Droughtmaster — Brahman^4 x Shorthorn^4
Braford — Brahman^4 x Hereford^4
Brangus — Brahman^4 x Angus^4
Belmont Red — Africander^4 x Hereford^2 x Shorthorn^2

The above are now well-established but others,

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Table 1. Breed changes in Queensland.

Year	Total beef cattle (million)	Zebu + Zebu cross (million)
1930	4.4	Insignificant
1950	4.9	0.2 (4%)
1965	6.3	0.8 (13%)
1973	9.2	4.0 (43%)
1977	11.0	5.9 (54%)
1982	9.8	6.4 (65%)

Sources: 1930 Department of Agriculture and Stock Annual Report 1930-31.

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including Charbray, Sahford, and Simbra, will no doubt establish themselves in time. Nevertheless, according to the breed census, most commercial crossbred cattle are generally referred to by their owners simply as Brahman cross. These, as well as 'breeds' listed above, are often referred to collectively as Taurindicus cattle. Together with the pure *Bos indicus* breeds they are known as 'tropical' or 'tropically adapted' cattle.

Research by the Department of Primary Industries

Nearly all the breed evaluation work that has been done has been concerned with evaluating genotypes that have some *Bos indicus* component. The first responsibility of the Department has been for developmental type research and we have not attempted to duplicate the work of CSIRO on the physiology of tropical adaptation.

All early data came from simple trials on commercial properties and even today we see this as a very valuable component of research. The information that can be gained from a commercial cooperator is limited by constraints on experimental design, number of treatments, and frequency of data collection. However the work can be repeated over many different sites, over many years, and at comparatively little cost. The accumulation of data in this manner gives great confidence in the applicability of the results.

We would like to pay tribute to all of the many cooperators who have been prepared to put themselves to considerable extra work to help obtain data on genotype evaluation, but in particular to Mr P. Maynard of 'Mt Eugene'. Data on genotypes and selection procedures have been collected from Mt Eugene continuously since 1963, and as well as providing information of great value for extension, these data have also formed the basis for 16 scientific publications.

This developmental research has been backed up by work on the Swans Lagoon Beef Cattle Research Station in the dry tropics of north Queensland, and the Brigalow Research Station in central Queensland.

Most of the emphasis and most of our data relate to growth rate. This is an important commercial trait that is highly heritable and easily measurable. It is not possible to directly measure feed conversion efficiency in grazing animals. However, under the extensive grazing conditions prevalent in Queensland — and in many tropical situations — feed is normally grossly under-utilized and feed conversion is not therefore a vital consideration. Moreover, a model for feed conversion efficiency in tropical cattle, by Saithanoo and Goddard (1982), suggests that growth rate and feed efficiency are highly correlated.

In addition to growth, some data have been recorded on carcass traits, reproduction, milk yield, birth and weaning weights, resistance to diseases and parasites, and survival. In the following sections of this paper, we propose to give a brief review of results of completed work, a description of the objectives and methodology of present research, and a discussion of the results. For convenience the work is grouped in 3 sections viz:-

1. Evaluation of tropical cattle in relation to British breed performance.
2. Evaluation of different tropical genotypes.
3. Evaluations incorporating a component of the European *Bos taurus* breeds.

In tables and in the text the following abbreviations for breeds are used:-

Hereford and Poll Hereford	H	Droughtmaster	D
Shorthorn	S	Braford	Br
Simmental	Sim	Brahman	B
Chianina	C	Africander	A
Charolais	Cl	Sahiwal	Sah
Santa Gertrudis	SG	Belmont Red	BR

BX — Refers to Brahman cross cattle (usually

⅜-⅝ B) where the *Bos taurus* component (probably S or H) is not recorded. Where the breed component is known superscripts indicate the nominal genetic makeup.

British Breeds and Tropical Breeds

Growth Rate

Mawson (1956) was the first to publish comparative data. Over a period of 815 days BX steers gained 0.05 kg/day more than HxS steers. When steers are turned off at an age of 4½ years, as is common in Queensland, a daily advantage of only 0.05 kg represents a final live weight advantage of 82 kg, which is very significant commercially. Table 2 summarizes the results from 14 subsequent studies.

The results from all of the 14 other trials reported here, from various parts of Queensland, show a weight gain advantage to tropical cattle, generally exceeding 0.05 kg/day.

One draft of the Strachan *et al.* (1980) trial, one draft of Winks *et al.* (1979) cattle group, and one of Stubbs and Mayer's (1966) also showed only a small or no advantage to the tropical cattle. However, other drafts within these trials have given results consistent with the rest of the data. The only area from which evidence is lacking is in the Southern

Table 2. Summary of growth rate comparisons.

Reference and Site	Brit. Breed	Zebu Breed	Duration days or months	A.D.G. Brit. Breed (kg)	A.D.G. Zebu Breed (kg)	Advant. to Zebu	Init. Wt Brit. (kg)	Init. Wt Zebu (kg)
Mawson 1956 NQ DT	HxS	H^5xB^3	815	0.338	0.388	+0.05	146	168
Sullivan/Willis 1958 CQ DST	H	H^4 SG^4	774	0.418	0.516	+0.98	116	126
Arbuckle 1958 CQ DT	H	H^6 B^2	941	0.308	0.383	+0.075	217	221
Stubbs/Mayer 1966	H	H^5 B^3	361	0.637	0.651	+0.014	205	249
CQ DT	H	H^5 B^3	336	0.235	0.265	+0.030	288	323
Arthur *et al.* 1972 CQ DT	H	H^3 B^5	321	0.477	0.551	+0.074	188	220
Strachan *et al.*	H	H^4 B^4	30m	0.49	0.55	+0.06^x	205	218
1980 SQ DST	H	H^6 B^2		0.49	0.50	+0.01^o	205	228
Burns/Winks	H	H^6 B^2	316	0.270	0.337	+0.067	—	—
P. Com SQ DST			341	0.330	0.373	+0.043	—	—
Burns/Winks P. Com SQ DST	H	$H^4B^2A^2$	31m	0.30	0.35	+0.05^x	198	163
Thompson P. Com NQ DST	H	BX	436	0.288	0.328	+0.04^x	206	261
Mellor/Round 1974 NQ WT	S	B^4 S^4	4x12m	0.54	0.62	+0.08	259	259
Corlis/Taylor 1979 CQ DST	MG	MG^4B^4	302	0.331	0.454	+0.123^x	202	227
Dodt 1980	S	S^4 A^4	15m	0.19	0.36	+0.17^x	142	160
NQ AT	S	S^4Sah^4	15m	0.19	0.33	+0.14^x	142	156
Winks *et al.*	S	BX	9m	0.50	0.52	+0.02^o	190	233
1979 NQ WCT	S	BX	18m	0.52	0.58	+0.06^o	238	246
	S	BX	12m	0.41	0.46	+0.05^x	243	241
Dodt/Winks P. Com NQ DT	S	BX	1174	0.212	0.256	+0.044^x	238	302
Winks *et al.*	S	BX	125	1.04	1.14	+0.10^x	317	317
1977 NQ DT	S	BX	198	-0.246	-0.150	+0.096^x	276	286

x $P < 0.05$; o $P > 0.05$. No superscript indicates no statistical evaluation.
DT — Dry Tropics; DST — Dry subtropics; AT — Arid Tropics (under 550 mm of rain); WT — Wet Tropics (over 1000 mm), WCT — Wet Cool Tropics (altitude 700 m).
NQ = North Queensland; CQ = Central Queensland; SQ = Southern Queensland.

Downs region where Herefords still predominate. Recently completed trials comparing Herefords with HxA steers suggest a marginal advantage to the latter (Tierney, pers. comm.).

It is noticeable that the initial weight of the crossbred groups is invariably heavier than that of the British breeds when both originate from the same property. Where the weights are the same it is because groups have been selected on weight, and the British breeds are then invariably older.

The results in Table 2 do not appear to show any consistent relationship between the magnitude of the superiority of the tropical cattle and the level of nutrition as shown by average daily gain. These results are, however, the net gain over an extended period that includes periods of weight gain and weight loss. Such fluctuations might mask any relationship.

Robbins and Esdale (1982) examined data from Hereford and H^5 Sah^3 steers from weaning to slaughter. The regression of H Sah gain on H gain was linear and the slope indicated maximum advantage to the tropical cattle at low rates of gain and vice versa. This finding is consistent with the model of Vercoe and Frisch (1974) but not with observations and results elsewhere in Queensland.

Table 3 shows A.D.G. for discrete periods within trials. The two sets of data from Swans Lagoon show a marked advantage to the tropical cattle during periods of high A.D.G. and very little or no advantage during dry season weight loss periods. The data of Burns and Winks (pers. comm.) and of Thompson (pers. comm.) also demonstrate little advantage to tropical cattle when all animals are losing weight.

In all of these trials the actual live weight of the tropical genotypes was significantly higher than that

Table 3. Breed differences in relation to varying nutrition as expressed by A.D.G.

Reference	Site	Brit. Breed	Zebu Breed	Duration Days or Months	A.D.G. Brit. Breed (kg)	A.D.G. Zebu Breed (kg)	Advant. to Zebu Breed
Mawson 1956	Mt Garnett DT	H^4 S^4	HS^5 B^3	198	0.564	0.653	+0.089
				129	-0.296	-0.067	+0.029
				105	0.099	0.207	+0.108
				110	0.776	0.788	+0.012
				166	0.016	0.052	+0.036
				203	0.557	0.517	+0.040
Burns/Winks (Pers. comm.)	Peak Cross DST	H	$H^4B^2A^2$	11m	0.38	0.45	$+0.07^X$
				4m	-0.07	-0.06	$+0.01^O$
				3m	0.73	0.88	$+0.15^X$
				4m	-0.05	-0.12	-0.07
				9m	0.52	0.60	+0.08
Thompson (Pers. comm.)	Toorak AT	H	BX	99	-0.063	-0.150	-0.087^X
				99	0.020	0.205	$+0.185^X$
				84	0.822	0.958	$+0.136^O$
				67	0.356	0.386	+0.030
				87	0.414	0.344	-0.070^X
Winks *et al.* 1977	S. Lagoon DT	S	S^4 B^4	184	-0.022	-0.019	$+0.003^O$
				185	0.63	0.76	$+0.13^X$
		S	S^4 B^4	178	0.032	0.108	$+0.076^X$
				196	0.58	0.72	$+0.140^X$
Dodt/Winks (Pers. comm.)	S. Lagoon DT	S	BX	165	0.066	0.054	$+0.012^O$
				252	0.403	0.465	$+0.062^X$
				52	-0.788	-0.910	-0.122^X
				244	0.366	0.422	$+0.056^X$
				147	-0.444	-0.555	-0.111^X
				256	0.528	0.630	$+0.102^X$

x $P < 0.05$
o $P > 0.05$ (not significant).
No superscript — no statistical analysis.

of the *Bos taurus* cattle at the commencement of the period of weight loss. This may have had a bearing on the results. A general observation is that crossbred cattle are able to sustain longer periods of weight loss and are more likely to survive under adverse conditions.

No specific study has been made of the influence of age on the difference between genotypes. This would be difficult because of confounding dam and nutrition effects. However the data of Dodt (pers. comm.) and Tierney (pers. comm.) suggest that the differences in growth rate tend to be greater at an earlier age.

Carcass Traits

A limited number of trials have measured carcass weight, dressing percentage, and fat cover. The results are summarized in Table 4.

In every case the dressing percent of the tropical cattle is higher than that of the British breeds. In some sets of data this may be due, at least in part, to their heavier weight. This was not so in the work of Winks *et al.* (1979) or that of Mellor and Round (1974). In the former case, the two genotypes were slaughtered at similar live weights. Mellor and Round turned off their steers at different ages but at the same estimated degree of finish. In both cases dressing percentage was consistently about 2% in favour of the tropical genotypes.

Dodt (pers. comm.) followed the eruption of incisor teeth in Shorthorn and Brahman cross cattle on Swans Lagoon. The age of eruption of each pair of incisors was significantly younger for the Shorthorns. The age of eruption of the first and fourth pair of incisors for Shorthorn and Brahman cross steers was 727 and 755 days and 1396 and 1521 days, respectively. This is of importance when carcasses are aged by dentition.

Tyler *et al.* (1982) compared the extent of bruising in *Bos taurus* and Zebu crossbreds on two separate occasions. The different genotypes were transported both separately and in mixed groups. On no occasion was there any significant difference between genotypes although on each occasion the Zebu crosses did have a slightly higher mean bruise score. In two out of three occasions when muscle pH was measured it was significantly higher in *Bos taurus* cattle, with no difference between genotypes on the other occasion. These results were somewhat unexpected since higher pH and bruising are indicative of stress and fractiousness, which are supposedly more common in Brahman based breeds.

Reproduction

Measurement of relative fertility is very difficult because of the large numbers required and stringent experimental requirements. Holroyd *et al.* (1979a) compared conception and calving rates of Shorthorn and Brahman cross cows over 3 years, during which period there was no consistent breed effect, although there were significant differences, both ways, within years and within age classes. In one particularly dry

Table 4. Dressing %, carcass weight, and fat depth at 12/13th rib of *Bos taurus* and Taurindicus steers.

Reference			Dress. %		Carcass weight		Fat depth	
	Brit. Breed	Zebu Breed	Brit. Breed	Zebu Breed	Brit. Breed	Zebu Breed	Brit. Breed	Zebu Breed
Mellor and Round 1974	H	BX	51.6	52.9	263	306	—	—
	S	BX	51.23	53.63	218	228		
Strachan 1980	H	H^6B^2			260	278	9.63	10.16^{O}
	H	H^4B^4			260	291	9.63	11.57^{X}
Wood *et al.* 1981	H	H^4A^4	51.1	52.7^{X}	251	304^{X}	7.3	11.7^{X}
Winks *et al.* 1979	S	BX	50.2	52.9^{X}	248	264^{X}	8.1	6.4^{O}
	S	BX	52.8	54.7^{O}	316	334^{O}	18.4	9.3^{X}
	S	BX	48.2	52.0^{X}	146	190^{X}		
	S	BX	52.2	54.3^{O}	245	264^{O}		
	S	BX	46.9	50.3^{O}	198	194^{O}		
	S	BX	51.4	54.9^{X}	269	279^{O}		

season, it was necessary to feed for survival 25.7% of Shorthorn cows and only 12.5% of crossbreds.

In only one year was there any difference in the interval from calving to first oestrus. The interval was longer in the BX in the most favourable year when post partum anoestrus intervals were shortest. This is interesting in that it is often said that the BX breed will exhibit anoestrus more readily under adverse nutrition than the British breeds and that this is a survival mechanism.

In a survey of 28 north Queensland properties, Donaldson (1962) found that calf brandings as a percentage of cows mated was from 2.5% to 5% higher for Brahman cross cattle than for *Bos taurus*, mainly Shorthorn herds. Both the survival of calves and cows, and/or higher conception rates could be the reason for these differences.

Birth to Weaning

Birth weight, milk yield of dam, growth to weaning, and weaning weight are all related. Weaning weight per cow mated is often used as the final index of breeder productivity. Holroyd *et al.* (1979b) measured these parameters on Shorthorn and Brahman cross cows over 3 years and on two pasture types at Swans Lagoon. In every year and on each pasture the milk yield, calf growth rate, and calf weaning weight were significantly higher in the crossbred animals. The overall mean figures for the Shorthorn and crossbred animals were 3.73 kg and 4.81 kg daily milk yield, 0.581 kg and 0.725 kg average daily gain, and 134 kg and 163 kg weaning weight. On every occasion the crossbred calves were heavier at birth, by an average of 2.6 kg, although the differences were not always statistically significant.

Stubbs (1962) also compared milk yield and weaning weight of British breed and Brahman cross animals. Yields were 671 and 939 litres of milk whilst the crossbred weaners were 23 kg heavier than the Shorthorns.

Milk yield in both trials was estimated by weighing calves before and after suckling. This is probably not an accurate method of measuring actual lactation yield but should be an accurate means of making comparisons.

Diseases and Parasites

Tropical cattle are more resistant to a number of diseases and parasites than are *Bos taurus* cattle. In Queensland their greater resistance to ticks has been one of their most valuable traits (Hewetson 1971; Seifert 1971a; Seifert 1971b). Most of our research has looked at the effect on productivity of dipping crossbred cattle.

In south-east Queensland Burns and Winks (pers. comm.) compared the effects of tick and helminth control on the growth rate of Hereford, BX, and AX steers. Although undipped Herefords carried more ticks than the crossbred cattle, dipping did not improve the growth rate of any of the genotypes and growth rate was unrelated to tick numbers. However, control of helminths by 3 weekly drenching with Levamisole had a significant effect on growth rate. There was, however no breed by treatment interaction. These results are not in accordance with a model of Frisch (1976) that ascribed part of the superior growth of Zebu crossbreds to helminth and tick resistance.

Corlis and Taylor (pers. comm.) compared Murray Grey steers with Murray Grey x Brahman, half of which were treated with an anthelmintic at 4 weekly intervals. During some treatment periods, the treatment by breed interaction was significant or approaching significance, suggesting that the *Bos taurus* breed would respond more to drenching and was more susceptible to helminth infestation. Callow (Anon. 1981) found that high grade Sahiwal cattle, which had never previously been exposed to ticks or to tick borne disease, were less susceptible to babesiosis than were British breed cattle.

Dodt (1977) showed that bovine infectious keratoconjunctivitis (IBK) was less prevalent and less serious in BxS cows than it was in Shorthorn cows, with the latter suffering repeated infections. (Table 5).

Table 5. Percentage of cows affected by Infectious Bovine Keratoconjunctivitis (IBK).

Disease incidence	Shorthorn	BxS
No IBK	4	47
Mild IBK	43	46
Severe IBK	53	7

Comparison of Taurindicus Genotypes

For most areas of Queensland the overall superiority of genotypes incorporating some Zebu component had been firmly established by 1970. Since then our research has concentrated on examining differences between the various tropical genotypes, and the effects of selection procedures. Generally, differences between tropical genotypes have been small by comparison with the difference between straight *Bos taurus* and Zebu crosses. Such small differences, nevertheless, could be important commercially but their detection requires a more rigorous experimental procedure.

Growth

Records of growth rate have been recorded over many years on the commercial property 'Mt Eugene', near Rockhampton. Lapworth *et al.* (1976) were the first to publish growth data on steers out of H^4 B^4 and H^2 B^6 cows, the former mated to Brahman and Santa Gertrudis bulls, and the latter to Hereford bulls. There was a year by breed interaction over the 4 years suggesting that the genotypes with a higher Brahman content were better able to cope in bad years. Breed differences, when significant, were small.

Rudder *et al.* (1982a) and Corlis *et al.* (1980) looked at breed of sire effects on the progeny of 'high' and 'low' Brahman cows, also on Mt Eugene. The cows were Brahman/Hereford crosses with approximately ½ and ¾ Brahman content. Corlis recorded 539 progeny, over two years, by Brahman, Hereford, Santa Gertrudis, Droughtmaster and Belmont Red bulls. Rudder examined the growth of 886 progeny of Brahman and Hereford bulls annually over 8 years. In neither set of data were there significant breed-of-sire or breed-of-dam effects on weight per day of age up to sale at 33-41 months. Corlis did observe breed-of-sire by year interactions suggesting that the genotypes studied do vary in their relative performance according to seasonal conditions. Selection of heifers on live weight could have masked the real performance difference between dam genotypes. The inability to compare random representatives of each genotype is a theoretical draw-back to this type of study although it is no draw-back in deciding what to recommend under normal commercial management practices.

On another property in the Central Highlands, Rudder and Short (1978) inseminated Shorthorn and SxSah cows with semen from an Africander, a Brahman, and a Sahiwal bull. With only one sire of each breed, one cannot make conclusions about breed effects, but the lack of any difference between progeny of Shorthorn and crossbred cattle, even at weaning, is somewhat surprising.

One of the few studies that showed some difference between Zebu crosses was that of Barnett and Mayer (1982). At 1067 days, B^4 H^4, B^6 H^2 and BR^4 B^2 H^2 steers were 540 kg, 530 kg and 520 kg, respectively, ($P>0.05$). The B^4 H^4 steers were F_1 cattle and their superiority could be expected.

A comparison between successive generations has been made by Laing and Taylor (1982) and by Rudder *et al.* (1982b). Progeny of Hereford dams by H^2 Sah^6 bulls were compared with the second generation bred by *inter se* mating of these progeny. The second generation calves grew significantly faster to 384 days but by 583 days there was no difference. The early growth of the second generation animals would probably be due to the maternal effect of the first generation dams. Rudder *et al.* (1982b) looked at 3 generations starting with steers by BR bulls out of H^4 B^4 cows. In this trial the first generation was not disadvantaged in early life by a pure *Bos taurus* dam. There were two subsets of data, in both of which year-by-generation interactions were highly significant; generation effects themselves were significant in only one set of data, in which weaning and yearling weights increased in the later generations.

In north Queensland, Winks *et al.* (1978a,b) recorded birth weight, growth, carcass weight, and yield of saleable meat from S^4 B^4 and S^4 Sah^4 steers, both of the F_1 generation. There were significant breed differences in some years for some sub-periods, but these were not consistently in favour of one or the other genotype.

The Sahiwal cross carcass weights were 15 kg heavier in one year ($P>0.05$) but not in other years.

The presence of breed-by-year interactions and inconsistent breed effects suggests that there may be real genotype differences dependent on the current environment, but that the fluctuating environment will render these differences in growth rate of little practical significance.

Reproduction

Two sets of data from 'Mt Eugene' have shown that the F_1 taurus x indicus cows or cows approximating that composition are more fertile than the 'back cross'. Rudder *et al.* (1981) and (1976) analysed conception rates of five different genotypes. The results are shown in Table 6.

The H^5 B^3 were first cross animals. In both sets of data, breed had an effect on fertility, with H^5 B^3 and BR^4 B^2 H^2 consistently more fertile than the others.

Table 6. Pregnancy rates (%) of maiden heifers and lactating cows.

Col 1	2	3	4	5	6	7	8	9
Genotype	Yearling Heifers			Lactating Cows				
			2y	1-2y	1-3y	1-4y	1-5y	1-6y
B^6 H^2	83	76	38	76	78	81	83	80
H^5 B^3	95	85	87	89	91	91	93	93
SG^4 B^2 H^2	95	82	62	76	77	86	85	93
D^4 B^2 H^2	85		66					
BR^4 B^2 H^2	92		84					

Col 2 and 4 from Rudder *et al.* (1981); Cols 3, 5, 6, 7, 8, 9, from Rudder *et al.* (1976).
Cols 2, 3, 4, Breed effect sig. $P < 0.05$.
Cols 5, 6, 7, 8, 9, Breed effect sig. $P < 0.005$.

The higher fertility of the first cross H^5 B^3 is not unexpected. It is noteworthy that there was no difference between the Brahman back cross and the Santa Gertrudis and Droughtmaster crosses. The Belmont Red (A^4 S^2 H^2) on the other hand did retain a level of fertility similar to that of the first cross.

In north Queensland, Holroyd and O'Rourke (1980) compared reproductive performance of F_1 Shorthorn Brahman and Shorthorn Sahiwal breeders. There were no significant differences in conception rate, calving rate, or weaning weight. Losses between pregnancy test and weaning were 15.8% of Sahiwal cross calves compared with 6.6% of Brahman cross calves. Most of the Sahiwal losses occurred in the perinatal and early postnatal period.

On Swans Lagoon Research Station, postgraduate students and staff of the James Cook University have conducted, in conjunction with Departmental scientists, an extended research program on bull fertility. They have compared the four tropical genotypes established on the station, viz. S^4 B^4, S^2 B^6, S^4 Sah^4, S^2 Sah^6.

Wildeus *et al.* (1984a,b) studied pubertal development, including histology and development of testis and epididymis, semen production, and LH and testosterone levels. There were only small genotype differences in some parameters, with half Zebus tending to earlier puberty than the ¾ animals.

Winantea (1979) and Entwistle *et al.* (1980) compared testicular circumference (SC) and mean testis weight (MTWT), which in *Bos taurus* animals has been related to fertility. The Sahiwal crosses had significantly greater SC and MTWT than Brahman crosses. This has not yet been linked directly with fertility but Entwistle *et al.* did show significantly higher sperm production associated with larger testis size in the Sahiwal, and Wildeus and Entwistle (1982) also demonstrated greater sperm reserves in the Sahiwal.

Ndama *et al.* (1983) showed that luteinising hormone release induced by gonad releasing hormone was greater in ½ than ¾ Brahman bulls, but found no difference in testosterone levels.

Diseases

On many occasions tick counts have been carried out on taurindicus crosses without any evidence of marked breed differences between the various taurindicus breeds. However Holroyd (pers. comm.) has observed that Sahiwal crosses tend to carry less ticks than Brahman crosses, and the ¾ Zebu carries less than the ½ Zebu. Holroyd and Dunster (1978), in examining the effect of tick control on BX heifers, not only found higher A.D.G. in dipped animals but also recorded significant negative correlations between tick count and A.D.G. among undipped animals. This is the only record of such a correlation.

Donaldson and Aubray (1960) observed that 5 out of 6 Santa Gertrudis bulls were affected with posthitis while 6 Brahman bulls grazing the same paddock were not. This was associated with apparent differences in control over the sheath rather than differences in the anatomy of this structure.

European *Bos taurus*

During the early 1970s arrangements were made for importation of semen, previously not available. Substantial quantities of semen of European *Bos taurus* breeds, that had not until then been present in Australia, were imported. All of these breeds have a higher growth rate and heavier mature weight than the Hereford and Shorthorns that form the basis of most Australian herds. This semen was used over Hereford and Shorthorn cattle. Semen was augmented by the importation of a limited number of purebred females from New Zealand. The most numerous of the breeds that have become established as a consequence are the Simmental and Charolais. The general view has been that these breeds will be of value only under intensive conditions of high nutrition. However, if crossed with the Zebu breeds they may well provide a base for a genotype that is more productive than the existing taurindicus breeds.

They have not been present long enough to provide conclusive data but we have been able to make a few comparisons. Strachan *et al.* (1980) compared the performance of progeny of Hereford and HxB dams sired by Chianina, Brahman, and Hereford bulls. The $C^4 H^4$, $C^4 H^2$, B^2 steers produced carcasses of similar weight at 2 ½ years old. They were substantially heavier than the $H^6 B^2$ and H steers. The $H^4 B^4$ were intermediate.

Rudder *et al.* (1975) compared Charolais x Brahman and Brahman steers in central Queensland. The former grew markedly better, the A.D.G. to yearling being 0.620 kg for the $B^4 Cl^4$ as compared with 0.49 for the Brahman steers. Rudder *et al.* (1980) have also compared Limousin x B, Charolais x B, and Chianina x B and Brahman bulls on BX cows. There was no difference in pregnancy rates and no difference in progeny live weight at 370 days, although the Chianina cross calves were heavier at branding (82 days). Straight Brahman progeny were slightly lighter than the others but not significantly so and this is in contrast to his other study (Rudder *et al.* 1975).

Wood *et al.* (1982) compared the tick resistance of Simmental x Hereford and Limousin x Hereford with Africander x Hereford.

It had been alleged that the Limousin was resistant to ticks. Both of the *Bos taurus* crosses were similarly susceptible, in marked contrast to the resistance of the A x H.

Rudder *et al.* (1975) observed that there was no dystocia arising from the use of three Charolais sires on Brahman cows as might have been expected. This may have been due to the Brahman dams, as dystocia is rare in this breed.

Current Research

The Queensland Department of Primary Industries will continue to make use of opportunities to compare the performance of genotypes on commercial properties and to accumulate data on many sites — particularly in the arid west and in the south. However, more emphasis will be applied to examining the effects of selection procedures on those genotypes that we now know to be the most suitable for our environment.

On each of the two beef research stations there is a major project on genotype evaluation — although evaluation is not the sole objective of either project.

Brigalow Research Station

Three genotypes are being compared. One is a 'control' herd of Herefords. The two others, Simmental and Belmont Red, have been bred from a base Hereford herd. The Simmentals have been chosen as a model for the fast growing, late maturing, European type *Bos taurus* . The Belmont Reds on Brigalow will essentially be ½ Africander and ½ Hereford.

The Simmental herd is still in the grading-up process, and during this process we have been able to look at the performance of $H^2 Sim^6$, $H^4 Sim^4$, and $H^6 Sim^2$ genotypes in relation to each other and to the Herefords and Africander crosses. Every year the steer weaners are allocated to two groups. One is retained on the station and one sent to grow out in another environment. All are slaughtered at predetermined mean live weights.

Growth rate, fat depth, and carcass weight are recorded on all animals and on a proportion of each genotype we have also carried out whole side dissection, rib set dissection and chemical analysis of rib sets. So far three drafts have been sent to a relatively favourable environment on the Downs, and one draft has been sent to a feedlot. Future drafts will go to the arid areas of southwestern Queensland.

Reproductive performance, including dystocia incidence, is being recorded in the females.

When the Simmental upgrading program has been completed we will be looking at the ability of this breed to withstand periods of severe nutritional stress, which are all too common to Queensland.

On Brigalow Research Station, the Simmental cross growth rate has been about 12% greater than that of the Herefords. On the research station the $H^4 A^4$ has generally been a faster grower than either H or $H^6 Sim^2$ but not as fast as the $H^2 Sim^6$. On the Downs the $H^6 Sim^2$ has generally done as well as the $H^4 A^4$ suggesting that there may be some genotype environment interaction. However, data have not yet been fully analysed. Gain in the feedlot has, as was expected, favoured both the Herefords and Simmental crosses at the expense of the Africander cross.

Swans Lagoon Research Station

Here we have established five herds — a high grade Sahiwal herd and four Zebu cross Shorthorn herds, namely $S^4 B^4$, $S^4 Sah^4$, $S^2 B^6$, and $S^2 Sah^6$, each consisting of 150 breeders. The purpose is partly to evaluate the Sahiwal for breed production, either as a pure breed or as a cross, and also to study the effect of increasing the Zebu component in the crossbred.

Differences between these genotypes are not expected to be large and therefore it is essential that groups for comparison be truly comparable. This means that each herd must be balanced in terms of generation and age. This is now only just being achieved so that results to date would have to be viewed with caution. The project is measuring growth and carcass weights, reproduction, (including conception, calving, foetal and calf losses, and bull fertility), susceptibility to parasites and disease, and the heritability of these traits.

The Sahiwal has been selected in India for milk yield, but so far there is no evidence of greater pre-weaning growth in the Sahiwal cross. Higher peri- and post-natal losses among Sahiwal crosses appears to be an undesirable feature.

The big climatic variations between years will provide an opportunity to examine genotype-environment interactions. However, consideration may also be given at a later stage to growing-out progeny in different environments.

Relevance to Tropical Africa and Asia

The relevance of this work could be considered not only in terms of the relevance of the results but also the methodology, and perhaps in addition the facilities that could be used to obtain answers to specific problems in other countries.

The work has all been done in a climatic and nutritional environment that is very similar to large areas of tropical Africa and Asia, but the management environment is, of course, vastly different. We believe however, that management differences would affect not so much the relative performance of different genotypes but the relative importance of the various traits that have been examined. Resistance to disease and parasites, for instance, might be of relatively small importance where animals are kept intensively and can be regularly treated. On the other hand, resistance to disease might be even more important to these regions than in Queensland, if veterinary services or the veterinary knowledge of stock owners are inadequate. Under intensive conditions feed conversion, which is of little importance on extensive range, might be crucial.

Whilst the traits on which we place emphasis may not have the same economic priority in Africa and Asia, we do in most instances have the facility to record features that might be more important in those countries.

Much of the data that we have found particularly useful in an extension and advisory context has been gathered at little cost in simple comparisons under commercial conditions. The validity of such data lies in the fact that the work has been repeated on many occasions and on many sites. It is not possible to pool the data to examine statistically the magnitude of observed differences. However, the results provide information in which we can have confidence when comparisons are all in the same direction. Such a program might be more easily implemented in some African and Asian countries than a program of detailed multifactorial comparisons under strictly controlled conditions. Ideally the methods of simple and multifactional comparison should be combined.

Although some officers of the Department have been involved in a personal capacity with cattle development projects in Asia, we do not have any formal cooperative research. However, our institutions, particularly Swans Lagoon, have been used by postgraduate students from Asian, Pacific, African, and American countries studying at the James Cook University of North Queensland. For both large-scale grazing or pen experiments the facilities are excellent but there is little capacity for on-station laboratory work and we rely on support, not only from the Department's biochemical and pathology laboratories in Brisbane and Townsville, but also on the excellent laboratory facilities at the James Cook University and the newly established CSIRO unit of Tropical Animal Science in Townsville.

In conclusion, the knowledge that we have gained from our work, the methods we have used, and the facilities that we have available are all relevant to evaluating the different characteristics of the beef cattle breeds of tropical Asia and Africa.

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Productivity of some *Bos Indicus* Cross Genotypes in Subcoastal Northern Queensland

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DURING the past 30 years there has been a major change in the genetic structure of the north Queensland beef herd with the introduction of *Bos indicus* breed into predominantly Shorthorn and Hereford herds, in excess of 80% of the beef cattle population of the area now containing some *Bos indicus* infusions (Anon. 1983).

The Brahman breed has been the major contributor to this genetic change, though Sahiwals, and a Sanga breed, the Africander, have also been used, but to a lesser extent. These three genotypes have been used in crossbreeding programs or in the synthesis of derived breeds such as the Droughtmaster and Belmont Red.

The comparative performance of half-bred Brahman cross (BX) and Africander cross (AX) genotypes and crosses between these lines, has been well documented in studies on both research stations and commercial properties in Central Queensland (Seifert and Kennedy 1972; Seebeck 1973; Rudder *et al.* 1976; Seifert *et al.* 1980).

For the northern Queensland environment, however, only limited data are yet available on the performance of AX genotypes (Entwistle *et al.* 1984; Queensland Department of Primary Industries, unpublished data). Reproductive performance of ¾ AX cows has been substantially lower than ¾ BX, and growth rates of progeny of AX bulls appear to be lower than those of BX bulls when mated to BX cows (P.B. Hodge, pers. comm.).

The major breed evaluation project in north Queensland, the Swans Lagoon program, reported in detail elsewhere in this Workshop, involves a comparison of Sahiwal (SX) and Brahman (BX) crosses (half and three quarter). There appears to be general consensus amongst northern producers and extension workers that for effective tick control and reasonable levels of productivity in this environment, desirable *Bos indicus* levels should be between ½ and ¾. These and other aspects are being quantified in the Swans Lagoon program.

Because of the small genetic pool of the Africander and Sahiwal breeds, their main use is likely to be in crossbreeding programs with established Brahman cross herds. The Belmont breeding program to produce reciprocal crossbreds between the half-bred AX and BX lines is providing objective data on the usefulness of these crosses for that environment. However extrapolation of results from this study to other environments must be cautious since genotype-environment interactions may result in a different ranking of genotypes in different environments.

The objectives of the program reported here were to examine the usefulness of crosses amongst a number of *Bos indicus* breeds in a harsh environment in northern subcoastal Queensland; to attempt to determine the physiological reasons for differences between genotypes and crosses; and to measure traits that are of economic importance, e.g. fertility, growth rates, parasite resistance. The comparative performance of ¾ Brahman and Africander genotypes and their reciprocal crosses is being examined, and the performances of a ¾ Sahiwal x ¾ Africander line, which had been established in a crossbreeding program in north-western Queensland, is also being monitored. This paper reports some interim data on this program, covering the first 5 years of the study.

Materials and Methods

Location and Environmental Constraints

The study is being undertaken at the James Cook University Veterinary Research Station, 'Fletcherview', located 27 km north-east of Charters Towers (latitude 20°S; longitude 146°E) in the 'Basalt' region of the Upper Burdekin Valley. The environment and pastures are typical of much of the northern subcoastal spear grass region. Maximum summer temperatures can exceed 37°C, whilst frosts are common during the winter months, causing considerable deterioration in pasture quality.

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Average annual rainfall (90 year average) is 642 mm, 80% of which falls between December and March. The dry season (absence of effective rainfall and hence pasture growth) ranges from 6 to 9 months, and in the period to date, annual rainfall was either poorly distributed or below average in 3 of 5 years (1979 — 769 mm; 1980 — 603 mm; 1981 — 924 mm; 1982 — 353 mm; 1983 — 575 mm).

Native pastures are typical of the region, being predominantly spear grass (*Heteropogon contortus*) with *Bothriochloa* and *Dicanthium* spp. Some small areas of improved pastures of Buffel grass (*Cenchrus ciliaris*) are also present. Marked seasonal variations in pasture dry matter availability occur, with a wet season maximum of about 2000 kg/ha and a dry season minimum of about 800 kg/ha (Lemerle 1981). Stocking rates range from 1 beast/4-6 ha depending on seasonal conditions and pasture availability. The growth pattern of animals in this environment is typical of the seasonally-dry tropics, live weight gains occurring in the early-late wet season, followed by a variable period of live weight maintenance and a period of live weight loss. Average annual live weight gains in young growing cattle range from 100 to 130 kg.

Cattle ticks (*Boophilus microplus*) and buffalo fly (*Siphona exigua*) are endemic. A major build-up in tick numbers usually occurs initially in the late-wet/early-dry season (May-July) with a secondary peak often observed in September-October. Depending on seasonal conditions, internal parasite burdens (predominantly *Haemonchus placei; Cooperia* spp; *Oesophagostomum* spp) may limit growth rates in young cattle. There is no evidence of trichomoniasis infection in the herd; heifers and bulls are routinely vaccinated for vibriosis and while leptospirosis is endemic on the property, there is little evidence of clinical disease, or of foetal losses due to infection.

Animals

The F_2 generation ¾ Africander cross (AX) and F_1 generation ¾ Sahiwal x ¾ Africander cross (SX) cattle were transferred to the property early in 1978 from Toorak Research Station, north-west Queensland. The F_2 generation ¾ Brahman cross (BX) were purchased from Swans Lagoon in coastal north Queensland. Subsequent *inter-se* mating of the F_1 SX line resulted in F_2 generation SX. Commencing in 1980, reciprocal cross mating of the ¾ AX and ¾ BX lines was undertaken to produce a ¾ AXBX line for which only limited data are presently available. Replacement bulls have been obtained either from Belmont (¾ AX), Swans Lagoon (¾ BX) or selected on growth rate from within the SX line, and are used for two successive seasons.

Management

Breeding cows are run as one unit except during the restricted mating period of 3 months commencing in late January. In 1983, mating was restricted to 6 weeks due to severe drought conditions. Heifers are first mated at 24-27 months, and culling has been on the basis of failure to rear a calf in 2 successive years, on poor temperament, and on age (> 12 years). Breeder survival feeding (molasses-urea) of portion of the breeder herd was necessary in the 1980 dry season and in the 1982 drought, extending into the early part of 1983.

Calves are weaned at 6-8 months (June-July) and steer progeny are retained until 18 months. Severe drought conditions in early 1983 resulted in the enforced sale of all steer progeny on the property and hence growth rate data for this class of animal are incomplete.

Tick control has been minimal, with dipping of breeders three times in the 5 year period. As part of other experimental programs, some anthelminthic treatment of weaner cattle has been carried out in some year drops of progeny.

Observations

1. Breeder body weights and condition scores — at the start and end of mating, at weaning (June-July) and again in September-October. Progeny weaning weights, and weights at 12 and 18 months are recorded.

2. Pregnancy diagnosis — carried out about 2 months after completion of mating (annual conception rates) and again in September-October (to determine extent of prenatal losses).

3. Dates of birth and sex of calves recorded three times weekly during calving season.

4. Temperament scores recorded on breeders at PD, and on some year groups of progeny.

5. Tick counts were initially recorded in June-July from 1979 to 1981 but not in subsequent years because of extremely low tick counts.

6. Internal parasite burdens (helminths, coccidia) monitored in groups of weaner cattle from 1979 onwards. Some anthelminthic treatment programs were superimposed across genotypes and sexes in the 1980, 1981, and 1982 year drops.

Statistical Analyses

Data on growth rates were analysed by a least squares model involving breed, sex, and year effects and their interactions, with date of birth as a covariate (for 1979 data, date of birth information not available). Data on pregnancy rates and foetal ages were also analysed by a least squares model in which breed, year, age, and lactation effects and their interactions were examined. The analysis of pregnancy rates was carried out using logic transformation and assuming binomially distributed errors. Differences in growth rates between anthelminthic-treated and untreated weaners were examined using a model involving breed and sex, with date of birth as a covariate.

Results

Growth Patterns

Live weight changes (corrected for age) for the AX, SX, BX and AXBX lines from weaning to 18 months for the 1979-1983 drops are summarized in Table 1. Weaning weights were significantly lower in the AX than in either the SX, BX, or AXBX lines. Weight data on the AXBX are incomplete, however, only covering the 1981-83 drops. Weaning weights of steers were consistently higher than those of heifers. Weight differences between breeds were still apparent at 12 and 18 months with a similar ranking of the genotypes, i.e. lowest weights in the AX, highest in the BX, with the SX and AXBX intermediate. There were significant year-of-birth effects on live weights, which reflect marked between-year variations in seasonal conditions and hence in growth rates. For example, dry season conditions were extremely severe in 1980 and 1982, so that 12 month weights in these drops were reduced compared with similar weights in the 1981 and 1983 drops.

Reproductive Performance

Information on pregnancy rates and foetal ages (time of conception) is summarized in Table 2 for matings between 1979 and 1983.

Apart from the limited numbers of AXBX cows, pregnancy rates were highest in the SX lines, lowest in the AX line, with the BX being intermediate. Foetal age (time of conception) followed a similar pattern, conception occurring earliest in the F_1 SX and latest in the AX line. There were no differences in fertility between cows mated to AX bulls and those mated to BX bulls in the reciprocal cross program.

Table 1. Least squares means for weaning weight and weights at 12 and 18 months of age.

Class	Weaning	Weight (kg) 12 mth	18 mth
Breed:			
AX	120.1^a	161.5^a	216.9^a
SX	139.3^b	174.1^b	245.7^b
BX	145.1^b	186.2^c	266.6^c
AXBX	138.9^b	180.7^c	267.1^c
Sex:			
Heifer	133.9^a	170.9^a	247.3^a
Steer	146.2^b	180.4^b	261.3^b
Year of birth:			
1979	148.4*	186.4*	238.5*
1980	143.6	150.3	293.8
1981	122.7	160.3	256.5
1982	169.7	155.3	235.4**
1983	133.8	229.5**	—

*1979 data uncorrected for age.

**Heifer portion only — steers sold because of drought.

Within each column, means without a common superscript differ significantly ($P < 0.05$).

Table 2. Least squares means for genotype, age, and lactation effects on pregnancy rate and foetal age (1979-1983).

	n	Pregnancy rate (%)	Foetal age (mth)
Genotype:			
AX	200	46^b	3.33^b
F_1 SX	132	63^a	3.60^a
F_2 SX	140	63^a	3.36^b
BX	207	57^{ab}	3.40^{ab}
AXBX	9	93^c	3.49^{ab}
Age (yr):			
3 (heifer)	139	19^a	3.75^a
4	126	68^b	3.85^a
>5	423	82^c	4.09^b
Lactation:			
Lactating	331	20^a	3.92^a
Non-lactating	357	87^b	4.55^b

Within each factor, means without a common superscript differ significantly ($P < 0.05$).

Between-year variations in fertility were extremely wide (Table 3), reflecting differences in severity of nutritional stress during the previous dry season. These nutritional stresses had a marked and significant effect in depressing fertility in heifers and in lactating cows, which in turn reduced overall herd fertility. Heifer pregnancy rates (24-27 months mating) were extremely low (19%) and there was an average 67% difference in pregnancy rates between lactating and non-lactating cows.

Table 3. Year of mating effects on pregnancy rates.

Year	Pregnancy rate (%)	Dry season conditions previous year
1979	73	Moderate
1980	66	Very good
1981	20	Very severe
1982	86	Very good
1983 (6 week mating)	36	Drought

Foetal losses between successive pregnancy examinations have been from 1-5%, with further losses to weaning of 3-5%. The small amount of data limits any meaningful genotype comparisons, though bottle teats in the SX line may have contributed to some postnatal losses.

Tick Infestations

A detailed analysis of data on tick burdens in breeding cows collected between 1979 and 1981 has not yet been undertaken. However, preliminary examination of the data suggests that the AX line carried the heaviest tick burden, with little difference between the SX and BX lines. Earlier subsections of these data may be confounded by developing tick resistance since the AX and SX lines originated from a tick-free environment, whereas the BX line originated from an endemic area.

Internal Parasites

Marked between-year variations in the extent and distribution of rainfall have influenced helminth burdens in young weaner cattle. Helminth species involved have been primarily *Cooperia* spp, *Haemonchus placei*, and *Oesophagostomum radiatum*. Three separate studies (1980, 1981, 1982) have been undertaken to monitor changes in internal parasite burdens of weaned calves from 6 to 12 months, and to assess live weight responses to treatment regimes with a number of anthelminthics (1980 — Avermectin B_1a; 1981 — Levamisole; 1982 — Levamisole).

Data from these studies are summarised in Table 4. In general, internal parasite burdens in weaner cattle in this environment have been low (300-1000 epg) in comparison with other environments, the exception being periods when unseasonal rainfall shortly after weaning in early-mid winter has resulted in a build-up in infestation.

Responses to treatment have only occurred in one year (1980) in which there were severe dry season nutritional stresses. In that and the following year, parasite burdens were higher in AX than in SX or BX. Breed differences in response to treatment in 1980 were higher in AX than in either SX or BX, and highest mortality rates occurred in untreated AX weaners.

Table 4. Summarized data on comparative helminth burdens and responses to anthelminthic treatment of weaner cattle in three separate experiments.

	Year of experiment		
	1980[a]	1981[b]	1982[c]
Relative parasite burdens (epg):			
AX	+++	+++	Cell numbers
SX	++	++	too small
BX	++	++	for
AXBX	n.a.	+++	comparison
Live weight response to treatment (kg):			
1. Overall	Yes	No	No
2. Between breeds			
AX	30 kg **	13 kg ns	Cell numbers
SX	14 kg ns	11 kg ns	too small
BX	22 kg *	10 kg ns	for
AXBX	n.a.	6 kg	comparison
3. Between sexes	No	No	No
Mortalities in untreated:			
AX	3/11		
SX	1/24		
BX	0	Nil	Nil
AXBX	n.a.		

(a) Tahir 1982. (b) Tarigan 1982. (c) Salazar 1983.

+++ heavy; ** $P < 0.01$
++ medium; * $P < 0.05$
n.a. not available

Discussion

The data presented here represent information on a relatively small number of animals over a short (5 year) period, and hence any interpretation must be cautious.

The period of study has been characterized by extreme between-year variations in seasonal conditions, which are typical of the region. Variations in pasture quality and quantity have been reflected in considerable between-year differences in cattle growth rates, reproductive performance, and to a lesser extent differences in internal parasite burdens in young growing cattle.

In this environment, the performance of the ¾ AX genotypes has been inferior to that of the ¾ BX. Weaning weights and growth rates to 18 months have been lowest in the AX, highest in the BX, with the SX generally intermediate. Overall pregnancy rates in the AX line have been consistently lower, with wet-cow conception rates in this genotype being considerably lower than for other genotypes. Poor growth rates in the AX line resulting in failure of a high proportion of AX heifers to achieve adequate mating weights at 24-27 months have been a major contributor to very poor (19%) overall heifer pregnancy rates.

Environmental effects such as heavier tick burdens (confounded though with developing tick resistance) and greater internal parasite burdens may have contributed to the overall poorer performance of the AX line in this environment. However the overall performance of the ¾ AX line at Belmont has generally been less satisfactory than other lines (G.W. Seifert, pers. comm.) perhaps due to a fairly high level of inbreeding, and this feature may contribute to the poor performance of our AX line.

Growth rates and reproductive performance of the SX line (¾ Africander x ¾ Sahiwal) have been generally similar to those of the BX line. However culling of cows on the basis of poor temperament has tended to be heavier in the SX than in other lines.

The limited data on the AXBX precludes any meaningful comparisons at this stage, though growth rates of this line more closely approximate those of the BX parents. Insufficient data are available as yet to examine maternal and paternal contributions to any heterotic effects.

In addition to the productivity data reported here, other genotype comparisons being undertaken within the program include limited work on carcass characteristics; a number of reproductive physiology studies including female puberty and postpartum anoestrus; breed comparisons of seasonal changes in body composition, and relationships of body composition/body condition/body weight to fertility; genetic and maternal effects on behavioural traits, and possible differences between breeds in susceptibility to infectious agents (leptospirosis, range of viral diseases). The basic aims behind these programs have been to attempt to identify physiological and other reasons for differences between genotypes.

Differences in environments and in the genotypes used between Belmont and Fletcherview (½ versus ¾ blood) preclude any valid comparisons of results. However, our interim data suggest that the ranking of the AX and BX differs between these environments, and that at least for subcoastal northern Queensland, ¾ bred AX cattle have lower productivity than do ¾ BX.

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Identifying the Breeds to be Evaluated

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THE aims of this Workshop include the identification of specific breeds in the developing countries of South-east Asia and Africa which, on the basis of overall productivity or some special productive or adaptive character, need to be evaluated in comparison with a 'standard' breed in various environments.

This presupposes that sufficient is known about the breeds to enable such identification. On the basis of information presented at the First and Second SABRAO Workshops on Animal Genetic Resources (SABRAO 1980; Barker *et al.* 1982), it is considered that, at least for South-east Asia, very few breeds could be positively identified in this way. Nevertheless, the need for evaluation is undisputed and urgent, particularly as appropriate evaluation would provide the required data on overall productivity and on any special productive or adaptive characters.

Conservation and Utilization of Animal Genetic Resources

For many years, FAO has been concerned with this problem. A series of study group meetings has been organized (FAO 1966, 1968,1971, 1973), and FAO, with support from the UN Environmental Program, has surveyed the cattle breed situation in Europe and the Mediterranean basin, with particular emphasis on breeds threatened by extinction (FAO 1975). In the scientific community, the conservation of animal genetic resources was reviewed and discussed at both the First and Second World Congresses on Genetics Applied to Livestock Production (Mason 1974, Lauvergne 1982).

While it may well be impracticable to conserve all currently existing breeds, the emphasis has been placed on conservation for optimum immediate or possible future utilization. Potentially useful genetic material should not be lost, as genetic variation is the basic material of the animal breeder. We use it to mould our animal populations to our needs, but once lost, we cannot create it at will.

It is clear that some breeds in the developing countries are in immediate danger of loss through indiscriminate crossbreeding with exotic breeds, others are rare and in danger of extinction, while others are losing genes for high production because high performing animals are being withdrawn from breeding populations. Indiscriminate crossbreeding may pose the greatest threat. High production of breeds in developed countries relative to that of native breeds in developing countries has led in the past to unrealistic expectations of the potential for rapid improvement of the productivity in the developing countries through importation.

But there is now an increasing realization of the potential value of the native breeds — particularly in their adaptation to climatic and other stresses, and to traditional husbandry systems. This realization was voiced most strongly in the discussions at the FAO/UNEP Technical Consultation on Animal Genetic Resources Conservation and Management (FAO/UNEP 1981). In considering the value of native breeds, the focus on 'potential' needs to be stressed. In most cases, data are not available to identify the nature of specific adaptations, nor is the genetic basis known. Such specific adaptations for disease and parasite resistance, and for fertility and survival in stressful environments, may well depend, not on single loci, but on co-adapted gene complexes. In such cases, it is most imperative to identify and evaluate the breeds before they are effectively lost through crossbreeding, whether it be indiscriminate or planned. Once the integrity of any co-adapted gene complex is destroyed in the crossbred, it will be very difficult to recreate.

However, definition of this 'potential value' poses an immediate problem. The value of a particular breed may be that it carries unique genes for some specific trait or that it is significantly superior to all other breeds for a quantitative character. These can be determined by evaluation, but this problem emphasizes the need, not only for evaluation, but

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also for concurrent research to define in detail the traits to be considered. That is, what are the best biological packages for each major climate-management-husbandry system?

As has been emphasized previously (Barker 1982), it is essential that in most developing countries the majority of the livestock are kept by small farmers under traditional husbandry systems. As these systems are unlikely to change rapidly, the most suitable and most productive breeds are required for these systems. Crossbreeding with exotic breeds may improve production over that of native breeds, some native breeds may be better than others, crosses among some native breeds may be better than the parent breeds, but we cannot know whether they are or not without appropriate evaluation.

The Problem

Reference has been made to 'appropriate evaluation', but just what does that mean, and what does it entail? Evaluation may be defined as the comparison under the same conditions, of contemporary animals from different breeds, strains or crosses, with collection of objective data on them.

Thus, as has been specified previously (Barker 1980), appropriate evaluation will entail:

1. Defining the traits to be measured, together with methods of measurement and of recording of the data collected.

2. Defining the environment-management system to be used for the evaluation experiments. This should be the normal environment for the industry in which the breeds being evaluated would be used, or a potential environment that might be used in the near future, economic and other circumstances permitting.

3. Defining the breeds and crossbreds to be included in the evaluation.

4. Defining the experimental design to be sure of a high probability of detecting differences of practical or economic magnitude.

In order to ensure that the evaluation is adequately done, as well as being appropriate, one should add a fifth specification, viz. that the evaluation experiment be completed according to the defined experimental protocol.

If these specifications are accepted as a reasonable basis for appropriate evaluation, then each evaluation experiment will need to be large-scale, may involve more than one environment, and should include lifetime productivity, so that viability (adaptive and disease resistance traits) and reproductive performance are fully evaluated. This poses part of the problem, but the major question is still — what should be evaluated?

So far reference has been made mainly to breeds, but many of the 'breeds' of the developing countries are very ill-defined. Geographically separate populations may be as different genetically as some of the different breeds so that these different strains should be evaluated separately. Further, crosses between different breeds and strains, both native and exotic, should be considered for evaluation.

Therefore the major problem is that, given the wealth of breeds, strains and geographically separate populations to be considered, it obviously will not be possible to evaluate all of them with the limited technical and financial resources available.

The Solution

Clearly some choice will have to be made of those breeds and strains that should have the highest priority for evaluation. Initially, this choice must be somewhat *ad hoc*, and based on whatever information is available on each of the various breeds and strains.

But even in the short term, this is just not good enough, and it has been argued for some time (e.g. Barker 1980) that the solution to the dilemma is to determine the genetic relationships among the breeds, strains, and populations of each species of livestock, so that they may be grouped into sets that are genetically similar, and then to include in evaluation experiments one representative from each set.

This approach has had substantial support, although it is yet to be implemented. For example, the Recommendations of the Second SABRAO Workshop include: 'That estimates of genetic distance among native populations of the SABRAO region be encouraged, so that a sound, objective definition of the existing breeds and strains within each species can be obtained.'

More recently, the first meeting of the FAO/UNEP Joint Expert Panel on Animal Genetic Resources Conservation and Management (Rome, October, 1983) included in its recommendations: 'The Panel noted that information on genetic distances between breeds of domestic animals would be of value in deciding priorities for action on breed conservation and management, and recommended that research on this topic be encouraged.'

The Method

Although this approach has not been used yet to determine candidate breeds, strains, etc. for evaluation studies, the methodology is well-developed and in fact has been used in studies of relationships among livestock breeds.

The methods derive from studies in evolutionary genetics, where interest has focused on the genetic differentiation of populations, races, subspecies, species, and higher taxonomic categories, and on evolutionary relationships. Two concepts are of prime importance, viz. genetic distance and phylogeny.

Genetic distance is a measure, expressed as a single number, of the genetic difference between two populations, determined as a function of differences between them in gene frequencies.

A phylogeny is an evolutionary history, where the evolutionary relationships among taxa are usually presented diagrammatically as a phylogenetic tree, i.e. a two-dimensional pattern of nodes and branches, where closely related taxa are placed on adjacent terminal branches, and distantly related taxa may be separated by many nodes.

The major aspects of the phylogeny of plants and animals have been derived from morphological criteria, studying both fossil and living organisms. Strictly, morphological affinity demonstrates similarity only, and does not necessarily give the real (i.e. genetic) phylogeny. With the advent of immunogenetics, however, the genotypes of individual animals can be determined for a number of loci specifying antigenic structures of red blood cell membranes (i.e. blood groups). More recently, developments in biochemical genetics have allowed characterization of genotypes at loci specifying various proteins, most usually enzymes, using the technique of electrophoresis. Therefore gene frequency data may be obtained for the populations under study; these may then be used to estimate genetic distances between each pair of populations, and then these distances used to construct a phylogenetic tree. The techniques and analytical methods, in the context of their application in evolutionary studies, are reviewed by Ferguson (1980).

If two populations are, for geographic or reproductive reasons, genetically isolated from each other (i.e. no gene flow between them), they will tend to accumulate different genes. The reasons for this differentiation will be mutation, selection, and random genetic drift. Thus, if gene frequency data are available for only one or a few loci, the estimated genetic distances and any phylogenetic tree will not be reliable. But if a large number of loci is used, effects of genetic drift varying among loci or effects of selection (either natural or artificial) varying for different loci will be averaged out. In addition, the loci used should be ideally a random sample of the genome. Whether the loci that can be assayed electrophoretically are a random sample of the genome is not known. There is some evidence to suggest that it is not an unreasonable assumption (Gunawan 1981), while other evidence indicates that these loci are not an unbiased sample (Leigh Brown and Langley 1979). However, with analyses based on a large number of loci spread throughout the genome, the variation observed within populations and the genetic distances between them will be influenced by many other genes that are linked to the electrophoretic loci. Thus the method will be sampling a larger fraction of the genome (although indirectly and to an unknown degree), and conclusions will apply to the gene complexes marked by the electrophoretic loci, and not just to these loci alone (Brown 1978).

The best measure of genetic distance would be the number of nucleotide or codon differences per unit length of DNA, i.e. differences in the genetic material itself, rather than in the protein products of the genes. While nucleotide sequencing is still very expensive and time-consuming, current advances in molecular genetics and associated technology are such that this information will be sought and will be available in the not-too-distant future. Indirect methods of nucleic acid analysis, such as restriction endonuclease analysis or DNA hybridization, are available, but for the immediate future, gene frequency data based on electrophoretic or immunological techniques will provide the most practical approach for phylogenetic studies.

One problem with the electrophoretic technique is that routine procedures using only one condition of electrophoresis do not detect all the variation within, or differences between, populations. Recent studies, however, have shown that previously unknown variants can be detected using sequential electrophoresis with varying pH or gel concentration (Coyne 1982; Keith 1983). For some loci, the number of variants detected is increased dramatically, greatly increasing the sensitivity of differentiation of the populations being studied. Application of sequential procedures will be essential in studies of livestock populations to maximize the accuracy of estimation of genetic relationships, and will be facilitated by the availability of a simple, newly developed technique using cellulose acetate plates, which is sensitive, fast and cheap (Easteal and Boussy, pers. comm.).

For all loci to be analyzed, a detailed sampling strategy must be specified. The sampling procedure should be standardized for age, sex, and tissue type of the animals, in order to be as sure as possible of homology of the loci in the different populations studied.

Several measures of genetic distance based on gene frequency differences between populations have been proposed (e.g. Cavalli-Sforza and Edwards 1967; Balakrishnan and Sanghvi 1968; Hedrick 1971; Rogers 1972; and Nei 1972). These measures are mathematically rather diverse, and for some, their biological interpretation is not clear (Nei 1973). If the rate of gene substitution per year is constant, Nei's standard genetic distance is linearly related to the time after divergence of two populations. Further, the standard errors of Nei's distance statistics can be estimated (Nei and Roychoudhury 1974). For these reasons, Nei's genetic distance measures have been the most widely used in studies in evolutionary biology.

As the mathematical properties and biological bases of the various measures do differ, it is conceivable that different distance measures could lead to different interpretations of the phylogenetic relationships among some sets of populations, with no way of determining the 'best' phylogeny, i.e. the one closest to the true phylogeny. However, the correlations among various distance measures have been found to be generally very high (Hedrick 1975; Chakraborty and Tateno 1976), particularly when applied to local populations within a species (i.e. equivalent to livestock breeds or strains).

A new measure of genetic distance, based on the coancestry coefficient, has been proposed recently (Reynolds *et al.* 1983). This measure is most useful for short-term evolution such as the divergence between livestock breeds. The variance of the distance value can be estimated, and it would seem the best measure for our purpose.

For the construction of phylogenetic trees, again a variety of methods have been proposed (e.g. Kidd and Sgaramella-Zonta 1971; Sneath and Sokal 1973; Felsenstein 1981), but here only the principle will be illustrated. When a tree is derived for a set of incompletely isolated populations (such as the livestock strains or breeds to which these methods are to be applied), it will not represent the real evolutionary history in terms of divergence times, unless the rate of evolution is constant in different lineages for a given protein. For present purposes, however, this does not matter, as the tree will represent the genetic relationships among the populations at the time the gene frequency survey is made. In this case, the tree produced is generally called a dendrogram.

Once the matrix of genetic distances among all pairs of populations has been produced, the simplest method to produce a dendrogram is the unweighted pair group method with arithmetic means (Sneath and Sokal 1973). For example, suppose there are four populations with genetic distances as follows:

Population	1	2	3
2	.050		
3	.066	.016	
4	.064	.080	.090

The first two populations to be clustered are those with the smallest genetic distance. These two are then combined and taken as a single group, and new estimates of distance between this combined group and other populations are calculated. This procedure is followed until all populations are clustered.

In the example, the distance between populations 2 and 3 is smallest, so these are clustered with a branching point at a distance of 0.016. These are then combined into a single group, and the new estimates calculated as arithmetic averages, to give:

Population	1	2/3
2/3	.058	
4	.064	.085

The next most similar pair then are 1 and 2/3 at a distance of 0.058, and the final cluster is population 4 with 1/2/3 at a distance of 0.078. In dendrogram form (Figure 1), all of the information in the matrix of genetic distances is readily visualized.

If this example represented data on four candidate populations for evaluation studies, if only two could be tested, and no other information were available, then population 4 and one of either 2 or 3 should be chosen.

In identifying candidate breeds for evaluation, it would be desirable to have genotype data for a large sample of variable loci so that reliable genetic distance estimates will be made. A reasonably large number of loci (say 20 to 30) might be readily assayed, i.e. blood group antd electrophoretic techniques are already defined, but some proportion of these almost certainly will be monomorphic in the populations studied. That is, all populations will be

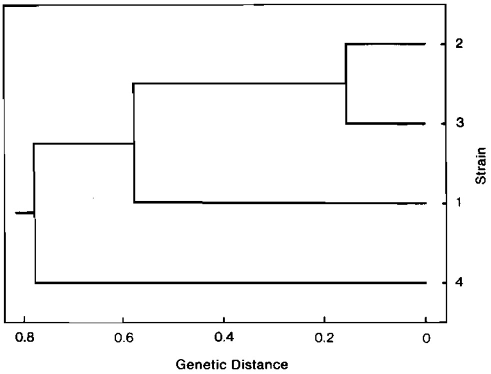

Fig. 1. Dendrogram of the genetic relationships among four populations.

homozygous for the same allele at certain loci, and these loci will not help to differentiate the populations. However, it must be recognized that the method does not end with the first sample of individuals tested from each population, nor with the initial sample of loci that are assayed. Additional samples from the same populations, new populations, or data on additional loci can be added to the gene frequency data base at any time to update or expand the analyses.

Other Benefits

While the method is proposed to attach a specific problem and to provide specific information, additional information of value also will flow directly from the data obtained.

Because genotypes of individuals are ascertained, the genetic structure of each population studied can be defined in terms of levels of inbreeding and amount of genetic variation.

At this time, very little is known about the mechanisms maintaining genetic variation at polymorphic enzyme loci. At some of the loci, variation is probably actively maintained by heterozygote superiority, i.e. higher fitness of heterozygotes in terms of survival or reproduction. In such cases, a controlled crossbreeding program to deliberately create heterozygotes would contribute to improving just those characters that are difficult to improve by selective breeding (Robertson 1966).

Finally, the estimated genetic distances among populations could be useful in predicting the expected heterosis in crosses between particular pairs of populations (Goddard and Ahmed 1982), which would be of value in formulating breeding policies.

Conclusion

The arguments presented are predicated on the assumption that insufficient data are currently available to identify breeds and strains that should have highest priority for evaluation. Clearly, some judgement can and will have to be made on breeds and strains for immediate evaluation, and it is not suggested that evaluation should wait until genetic distance studies are completed.

However, the results from the approach proposed will help to rationalize research programs, to minimize inefficient use of scarce resources in breed evaluation, and will facilitate choice of the most suitable and productive breeds for the traditional husbandry systems of the smallfarmer.

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Information Systems for Animal Breeding Research and ACIAR

A.E. McClintock*

BEFORE rushing into a data recording system (for example, milk recording of dairy cows) it is essential to ask 'are the questions that are being asked relevant'?. Often the data collected are obtained merely because they are easy to collect. There seems to be little point in establishing a project unless unequivocal decisions can be made when it is completed. Thus not only must all the relevant factors be recorded but the scale of the project must be large enough and the design appropriate to produce sufficiently accurate results. Too often projects are doomed to failure before they start. The statistical models and detailed procedures that will be used to analyse the data should be specified at the planning stages.

There are two levels of data collection; the first, and in my opinion the most important, relates to the gross profitability of the farming enterprise. The second level is related to understanding the biology of the animal. The second level is useless unless it is related to the first level.

The economic study might include an analysis of:

- Projected stability of prices and costs.
- Values of products sold.
- Costs of establishing support services (if needed), e.g. AI, veterinary, and product processing.
- Costs of inputs, e.g. feeds, labour, buildings.

A biological study might involve collection of the following data:

- Milk output at various ages (fat and protein).
- Weights at various ages and/or linear measurements.
- Reproductive performance.
- Reasons for disposal/loss.
- Quantity and quality of feed consumed.
- Health status.

A project involving the use of semen from *Bos taurus* must examine the profitability of both the native cattle and the crossbreds. In addition, the overall profitability must be related to biological measures including production (e.g. meat or milk) and inputs (food, drugs, and labour).

If it is considered that an evaluation of the F_2 or the backcross of F_1 to the native cattle cannot be undertaken, semen from the native cattle should be frozen. Sufficient should be frozen to enable the re-establishment of the native population should it eventually transpire that the F_2 were less desirable than the native cattle.

Form Design

Data collection forms are central to any recording system; without well-designed, compatible forms the system will almost certainly fail. Some aspects of form design that are related to the collection of animal data are worthy of special mention.

1. Errors will occur. An important difference between a good recording system and a bad one is in the way that errors are corrected. Is the error handling procedure an integral part of the system, or a desperate, last minute attempt to patch up a sinking ship?

2. It is common practice to issue identity codes (numbers and/or letters) to animals. In the banking world where clients are identified routinely by account numbers, the use of 'Check Digits' is routine. These check digits allow the internal validity of a number to be checked and transpositions etc. detected within the computer. It is important to use such a system (e.g. Modulus 11) for animal recording.

3. To minimize the chances of transposition errors, computer lists of animals sorted in some appropriate order can be generated and new data can then be written onto these sheets. This technique is routinely used in most milk recording schemes. It is useful to print the date by which the records should be processed.

4. Form design must take into account the views of both the data collectors and key punch operators. The use of multi-part stationery can allow the 'top copy' to be designed for the data collector while the

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second copy can show other information to assist the key punch operator (e.g. column numbers for each field).

5. It is relatively cheap to print detailed notes on the reverse side of each form that show the meaning of any codes used. If changes of codes take place at some later point in time, it can save difficulty if these codes are shown; the data when a form is reprinted should always be shown for similar reasons.

Liaison

Usually at the farm or village level there will be various activities performed by different staff, e.g. AI, milk recording, veterinary, and agronomy inputs. There is considerable advantage in the joint administration of all these activities at the local level. A slow response to resolving recording problems in any one of these areas can be expected if the management structures for each area only liaise at the 'head office' level. Clearly the usefulness of a particular record depends on full and accurate data collection throughout the system.

The designers of the computer filing system must be made to identify closely with the aims of the project and anticipate likely recording problems. They must be exposed to the reality of field conditions, before designing the system.

Identification

Whether one is collecting information on farms, herds, cows or sires it is wise to use Check Digits to avoid corrupting the data files. Identities should not be re-used — they should be unique.

Dates of mating should be recorded and compared with dates of birth. Birth dates and calf identification should be recorded at birth and validated at that point, not 2 years later. It is not realistic to expect a strictly sequential series of numbers on the central data files. The computers will easily store and retrieve records in indexed sequential files with a minimum of wasted space. Ease of application is more important and this usually entails a system of cows identified within years of birth within the herd (or village) of current ownership. This is satisfactory providing animals do not move between herds (or villages). The central filing system will have to retain full data on movements of animals between herds if this occurs. Full data includes date of transfer and old identity in full. Also the reason for transfer could be of help in the interpretation of the results.

A Central Data Processing System at Armidale

On the campus of the University of New England, Armidale, there are three distinct but interrelated groups:

1. Agricultural Business Research Institute (ABRI): This Institute provides farm costing and advisory services to producers in various agricultural industries both in Australia and overseas. The Institute's computer is also used for the central recording for a large number of beef and dairy cows. Growth, conformation, and parentage details are currently stored and processed.

2. Animal Genetics and Breeding Unit (AGBU): This Unit provides specialist advice in the area of genetics as applied to practical beef and dairy cattle breeding programs. There is expertise in data processing for more complex survey records where linear models are necessary to avoid the biases caused by partial confounding. The Unit is not involved in data preparation but is currently able to process data files presented on computer tapes by, for example, ABRI using the University's mainframe computer.

3. University Computer Centre: The University runs a DEC2060 computer for use by staff and students. There is an excellent support team at the Centre that ensures that the most useful software and hardware is made available to users. In particular, the interface between mainframes and micro-computers is recognized with the provision of suitable protocols for the transfer of data down serial lines. There is considerable experience in decoding data files from a large variety of mainframe installations around the world.

Software

AGBU has developed a library of a useful set of software utilities for fitting linear models to field data. This includes traditional fixed effects models and also the newer mixed models (best linear unbiased predictor). Various visitors, who have spent sabbatical leave at the Unit, have contributed software to the library.

Considerable time and effort is required to install, test, and become competent in the use of such software. It is not a wise use of resources to attempt to replicate this expertise for every project.

Hardware

The increasing availability of micro-computers at reasonable cost could facilitate the collection, verification, and editing of data close to its source. This has the distinct advantage that error detection and correction can be done quickly. However, the widespread use of micro-computers for this purpose presupposes that the skills needed to operate them are available and that a central resource group is founded to supply and maintain software. One possible way of avoiding the inherent unreliability of floppy disks for data storage would be to use telephone lines for accessing a central data-base; this need not be a large machine to be effective.

There is a distinct difference between the complexity of applying mixed model analyses and running a simple data storage and editing facility on a micro. The micro-computer could be made to perform very complex analyses but the time required to write suitable programs and the time required for these programs to run would reduce the desirability of this option. More importantly, however, the expertise required for handling such complex analyses is not widely available, particularly when unforeseen problems arise.

One possible method of collecting, storing, collating, and analysing data would involve setting up, as part of the project, micro-computer expertise in each country with the task of defining the data collection system (form-design, data collection and editing software with prompts in the local language).

This key person would be responsible for running a micro-computer with a hard disk where all data from the project would be stored. A telephone modem link would provide access to the data from cheap but intelligent data entry equipment from any remote site with a telephone. The quality of telephone lines will dictate whether this option is realistic. The alternative is the cassette tape.

This person would also be responsible for writing user-friendly software for the intelligent data entry equipment and for training the users in its use. Ideally the design of the central micro-computer (hardware and most of the software) should be done at some central site (perhaps Armidale).

The advantage of central planning would be that if several projects were being run in several countries there would be a degree of compatability. For example, problems solved at one site may help at another. The disadvantage with this central planning concept is that modifications will be needed for each language unless English is taken as the standard.

The central micro-computer would create printouts on which additional data would be written. Then, depending on the exact circumstances, these sheets could be either sent back to the central micro-computer site or could be used for typing data into the intelligent data entry devices by the data collectors. The intelligent data collection devices could carry sufficient information in CMOS memory and also help validate it.

Conclusion

The benefits obtainable from the careful and detailed design of the total information system cannot be underestimated. The appointment of an appropriate Project Leader, although not mentioned, is clearly vital.

The scale of meaningful and effective animal breeding research is substantial; it requires considerable time and numbers of records.

Conclusions and Recommendations

THE evaluation of indigenous genotypes of large ruminants is urgently needed in developing countries to indicate what avenues are available to improve productivity. There are few evaluations that are sufficiently comprehensive to enable decisions to be made about the relative impact on productivity of environmental and genetic change. This is due in part to the lack of technical input, trained manpower, and funds in developing countries.

The Workshop therefore commends evaluation studies to ACIAR as a matter of high priority to assist developing countries, using Australian resources and expertise in their design, establishment, and execution.

Discussion groups considered the need for evaluation under the following headings of (a) swamp buffalo, (b) cattle, predominantly for meat production, and (c) multipurpose cattle.

However, in answering the fundamental question — evaluation for what objectives? — it is necessary to recognize the markedly different systems of agricultural production that exist in Africa and Asia and the role of both humans and livestock in them.

Marked differences exist between the traditional systems of Africa and Asia. Africa has some traditional systems that depend entirely on livestock (large and small ruminants) and are often characterized by transhumance, although in some parts, e.g. the highlands of East and Southern Africa, livestock form a significant part of more complex agricultural systems. In Asia, livestock are very much part of an integrated agricultural system, contributing to and dependent on major production of rice and other crops. Ranch systems have developed in parts of Africa and Asia (Philippines, South Pacific, Indonesia) and a recent trend in some countries in Asia has been towards ranch systems to provide cattle to small holders for rearing. The swamp buffalo is used only in traditional systems where it has a multipurpose role. The relative importance of each role varies throughout the region.

Common factors to production in developing countries are low reproductive rate, high calf mortality, low milk production, and slow growth. There are national livestock investigation and improvement centres in most countries and a major aim is to develop and distribute improved types. This implies an evaluation procedure.

Evaluation of cattle and buffalo should be carried out in a number of ways. The first priority is to obtain baseline productivity data (e.g. fertility, mortality, and growth rate) under the prevailing conditions. The direct determinants of productivity and how these are modified by environmental factors such as climate, nutrition, parasites, and other diseases should be established. Provided evaluation is done systematically and on an interdisciplinary basis a variety of avenues for improvement of productivity will emerge, including genetic, environmental, and sociological options.

Whilst recognizing the difficulties associated with making recommendations for such diverse ecological situations, cultural backgrounds and expectations, the Workshop identified priority research areas for traditional and ranch systems.

Traditional Systems

Asia — Buffalo

Conclusions:

1. Increased draught output is the greatest need in all countries of the region (possibly with the exception of Malaysia), with increased output of beef of secondary consideration. Increased milk production (mainly in the Philippines) and increased output of by-products including hides and horns for home industry, and dung, both for fertilizer and fuel, are of varying minor importance from country to country.
2. Low levels of nutrition are a major constraint to buffalo productivity in all countries of the region and low quality agro-industrial by-products are likely to remain or to increase in importance as a the major feed source for swamp buffaloes. Consequently, there is a need to develop systems that will maximize both the utilization of these by-products and the productivity of buffaloes that are reared on these diets.
3. There is an urgent need to increase both calf survival and cow reproductive rates in all countries of the region and whilst high calf mortalities are generally related to infestation by internal parasites (particularly *Toxacara vitulorum*) and infection with diseases (particularly haemorrhagic

septicaemia) the causes of low reproductive rate are many, vary from region to region, and may be of both genetic and environmental origin (including socio-economic).

4. There has been no comparative evaluation of the different strains and breeds from SE Asia, the Indian subcontinent, the Mediterranean region or Europe. Neither the magnitude nor causes of differences in productivity between these breeds and strains, reared under both 'traditional' and 'improved' conditions, nor the appropriate source of genes for use in the improvement of any given strain are known.

Recommendations:

1. Attempts should be made to identify genetically different populations (i.e. strains) of the swamp buffalo (including the use of biochemical and blood group markers to estimate genetic distances among strains) and to evaluate those strains. Potential candidate populations could be those that are known, or thought to express, desirable productive attributes related to high draught capacity, high reproductive rate, low calf mortality, high heat tolerance, high resistance to parasites and diseases, or the ability to utilize efficiently low quality feedstuffs. Methods of evaluation should be such as to identify whether differences between populations are of genetic or environmental origin and whether different strains are best suited to particular production systems or environments. Comparative evaluation should extend beyond swamp buffalo strains to include the buffaloes of the Indian subcontinent, Europe, and the Mediterranean region. Methods for enhancing the value of comparative evaluation, including the use of reference breeds, should be considered.

2. Effort should be directed towards the development of efficient means for increasing draught output. This may come from an increase either in buffalo numbers, in draught capacity (possibly associated with increased live weight), or an increase in the efficiency of draught associated with an improvement in heat tolerance, a reduction in incidence of subclinical diseases, e.g. liver fluke infestation, or the design of better harness and equipment. Every attempt should be made to identify biological and socio-economic constraints associated with the simultaneous use of animals for draught, milk, and reproduction, and to develop techniques aimed at overcoming those constraints. This will require additional information on the physiology of reproduction, draught capacity, heat tolerance, lactation and nutrition, and the interactions that occur between these variables.

3. Efforts to increase numbers should be aimed at solving the joint problems of both low calf survival and low reproductive rates. Ways of implementing cost-efficient methods for control of internal parasites and vaccination against disease should be explored. The contribution of specific diseases to low calf survival should be investigated within each country. The reasons for high reproductive rates of some swamp buffalo populations should be identified and other such populations sought. If the reasons are identified as being of genetic origin, these populations should be investigated as possible sources of genes for high reproductive rate. Alternatively, if the reasons are of environmental origin, the knowledge should be used to improve reproductive rates of other populations. Techniques for increasing reproductive rate associated with the use of AI, the provision of adequate numbers of suitable bulls, and the improvement of environmental conditions should be further investigated. The contribution of specific diseases to low reproductive rates should be defined.

4. Ways should be sought to increase growth rates of swamp buffaloes, particularly on diets of low quality agro-industrial by-products. These increases may arise from improvement of diet quality, both by treatment to improve their utilization and by the addition of catalytic amounts of protected proteins or concentrates obtained wherever possible from locally available resources. In addition, the contribution of green forages to improvement of diet quality should be considered. The role of rumen manipulation and growth promotants on low quality diets should be investigated. Increases in growth may also be associated with genetic improvement in the efficiency of utilization of the already available or eventually attainable diets both for maintenance and growth. The possible existence of vitamin or mineral deficiencies on these low quality diets also should be investigated.

5. The socio-economic constraints to the implementation of already existing or eventually possible technology should be clearly defined and methods developed to try to overcome these constraints. This applies particularly to apparent

conflicts between desires of the small holder as opposed to requirements of the nation.

6. Coordinated cooperative research programs should be encouraged between countries of the region using the expertise of universities and other research institutes to realize the above goals.

Asia — Cattle

The major need is for an animal that can provide draught power and milk. With the exception of those situations where there is a ready market and demand for young calves, meat is seen as a by-product that accrues at the end of the animal's useful life.

Conclusions:

1. Some crossing with introduced breeds has already been carried out in attempts to increase productivity, especially in milk production. Information is available on only a few of the characteristics relevant to overall productivity indicating that evaluation of local cattle in relation to introduced breeds, either from within the region or from other areas, is urgently needed. Insufficient information is available on productivity and its components to allow a rational choice of suitable types or prediction of their value in different circumstances.
2. Important local breeds such as Kedah-Kelantan, 'Javanese Zebu', (in PNG), Madura, Grade Ongole, Bali, and Thai native cattle are priority candidates for use in improvement programs in meat production. The comparative work on the Local Indian Dairy Breed (LID) and Grati with Friesian crosses or the Australian Milking Zebu (AMZ) should be encouraged and expanded where improvement in milk production is desired.
3. The national government policies of most countries support improvements in cattle productivity through the use of more productive genotypes. Attempts that have been made to evaluate breeds for their contribution to improvements in the national herd have not been done systematically or on a comparative basis. Successful evaluation has been hindered also by the lack of trained personnel and resources.
4. In situations where there is no established market for young calves, e.g. Thailand, there is little incentive to improve reproduction rate; small mature size and low growth rates are then perceived as the major production components in need of improvement.
5. In situations where young calves can be marketed, or where cattle numbers are declining, improvements in reproduction rate are seen more important than increases in growth rate and mature size.
6. There is little information available either on the characteristics important for the improvement of draught power or on the interrelations between draught, lactation and reproduction, and the nutritional requirements to satisfy these demands collectively or individually.
7. Docility is a major consideration for smallholders particularly where there is limited previous experience with cattle.

Recommendations:

1. ACIAR should encourage and support national governments in the establishment of evaluation projects for indigenous breeds and their crosses with exotic breeds, for the components of productivity (e.g. reproduction rate, mortality, growth rate) and their determinants (e.g. parasite and disease resistance, heat tolerance, feed utilization). Studies on crossbreds need to include the F_2 and later generations.
2. The possibility of increasing mature size and growth rate, either by selection within the indigenous breeds or by breed substitution and crossing, should be investigated. Increases in these production components must be achieved without detriment to reproduction rate.
3. Efforts should be made to increase the nutritive value and the efficiency of utilization of the low quality diets based on agro-industrial by-products.
4. Studies on the desirable characteristics of draught animals and ways to improve the efficiency of harness and implements should be promoted. Methods to overcome the physiological constraints, e.g. pregnancy and lactation, associated with the use of cows for draught should be investigated.
5. The susceptibility of crossbred cattle to environmental stresses, e.g. parasites and diseases, inherent to these production systems, should be defined as part of the evaluation process.

Africa — Cattle

The emphasis in the African traditional systems is largely on milk production with draught and meat being usually of secondary importance. Individual herds may be large but the semi-nomadic life style is a significant impediment to improvement in many regions. There is a trend towards more settled pastoral production and integration with cropping programs.

Conclusions:

1. Information is available on relatively few breeds and on only a few production characters. The variation between breeds and the relative differences between breeds reared in different ecological zones are not known.
2. Major production losses arise through low reproductive rates and high calf mortality.
3. Crossbreeding with European breeds incurs significant losses in adaptation. Improvements in the level of management required to overcome this problem are difficult to implement in the present circumstances.
4. Efforts should be directed towards evaluating important local breeds such as the N'Dama, Tuli, N'guni, and Soketo Gudali for meat production and the Kenana and its cross with Friesian for milk production.

Recommendations:

1. ACIAR should encourage and support national governments in the establishment of evaluation projects for indigenous breeds and their crosses with exotic breeds in specific ecological regions.
2. Crossing between breeds from different ecological zones in Africa could be encouraged with a specific view to increasing reproductive rate and milk production without significantly changing the level of adaptation.
3. The resistance to specific diseases, particularly those currently amenable only to genetic methods of control, e.g. trypanosomiasis, dermatophylosis, should be defined for various genotypes.
4. The response of both indigenous breeds and crosses to changes in the level of nutrition should be defined in anticipation of greater integration with farming enterprises and an increased availability of crop residues and/or forage crops.
5. Environmental, and in some situations genetic, methods of improving reproduction rate, survival, and milk production, appropriate to the traditional systems of Africa, need greater research effort. In particular, determination of the improvement that can be made by the use of supplements based on agro-industrial by-products or forage crops should be regarded as a matter of high priority.

Ranch Systems

Asia and Africa

Ranch systems for meat production are common in parts of Asia, the South Pacific, and Africa. In Asia and the South Pacific they are based mainly on crosses with the Brahman and the Brahman-derived breeds, and to a lesser extent the Africander. In Africa the local breeds and improved strains of the local breeds (e.g. Boran, Tuli, Mashona, Keteku) are most used.

Conclusions:

1. The number of ranches is increasing in parts of Asia and the South Pacific, often in conjunction with smallholders who grow cattle bred on ranches in their own enterprise, e.g. palm plantations.
2. Reproductive rate of the Brahman-based breeds is frequently low when compared with indigenous breeds. Growth rate and mature size of the indigenous breeds need to be improved. Hence other breeds should be investigated.
3. There are instances where comparative productivity data have been collected but have not been analyzed, and other instances where comparative data could be relatively easily collected for a small input.

Recommendations:

1. Support from ACIAR and Australian institutions should be given to the analysis and interpretation of existing comparative data.
2. Collection of comparative data for productive and adaptive traits should be promoted; indigenous breeds should be included wherever possible. In the case of crossbreds these should include data from F_2 and later generations, particularly for reproduction rate.
3. In situations where crossbreeding results in an intolerable loss of adaptive attributes, selection studies for growth rate and mature size within indigenous breeds should be encouraged with a particular view to monitoring any possible effects on reproduction rate.
4. The need for mineral and other supplements needs to be established.

Guidelines on Methodology

1. All animal in comparisons should be born, reared, and measured throughout life at the same place at the same time. Accurate identification is essential.
2. All the components of productivity should be studied, including fertility, mortality, growth, milk production, as well as resistance to parasitic and other diseases, feed utilization, heat tolerance, and maintenance requirement.
3. On a population basis, herd structures, inputs, and offtakes need to be measured. This will also assist in economic evaluation. Nomadic systems present major problems in terms of improvements to production that probably can be solved but only with considerably greater expenditure of time and money than occurs at present. Since nomadism influences many cattle populations in Africa, research into ways of improving productivity that are commensurate with nomadism and the preservation of rangelands should be encouraged.
4. The use of reference breeds in comparative evaluation studies is desirable. Although the movement of animals between Asia and African countries is a problem, breeds from Australia, e.g. Brahman, AMZ, could be used by taking advantage of embryo transfer technology. Reference breeds must be adequately sampled to provide a broad genetic base.
5. A major reason for evaluation studies is to identify significant genotype x environment interactions and the reasons for them. Sites for evaluation are therefore of critical importance and need to be defined in terms of the prevailing environmental stresses and management inputs. Research stations frequently represent atypical but controllable conditions and provide an opportunity to 'simulate' a range of possible production situations.

Role of Australian Institutions and Scientists

Australia has the capacity to contribute expertise and finance towards assisting cooperating countries to pursue programs of evaluation and improvement of large ruminants. In the case of cattle, much of the required technology is well established and available. In the case of buffaloes, limited expertise and knowledge is available and the application of existing knowledge and expertise from cattle is an appropriate first step.

Australian institutions have considerable experience in evaluation work at all levels (i.e. the components of productivity as well as the underlying determinants), both within Australia and in tropical regions of Asia and Africa. Apart from collaborative work on the choice of candidate breeds to evaluate, the design and operation of the study and analysis of results, Australia has particular skills in fields that determine productivity, (namely environmental, reproductive, and nutritional physiology), and methods for the control of parasites and diseases that are of particular relevance to developing countries. Evaluation at all levels increases the avenues through which improvements will be possible and enables extrapolation of the findings to environments other than those in which the observations have been made.

Specific research may be required to solve problems that are only relevant to buffaloes, but given the multidisciplinary nature of these problems Australian scientists will be able to play a significant collaborative role.

Given the need for Australia to continue its efforts to improve the productivity of its own tropical cattle, cooperative programs with developing countries in Asia, South Pacific, and Africa will be mutually beneficial.

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