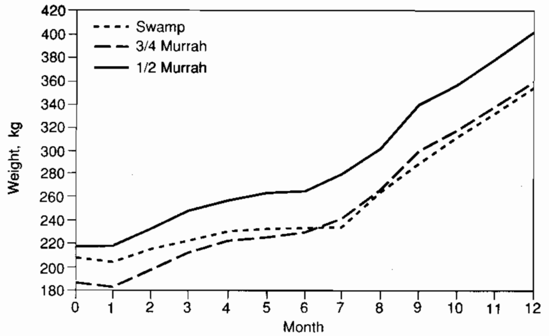
between sexes for any trait, in the analysis of covariance. In addition, there was no significant interaction between genotype and sex.



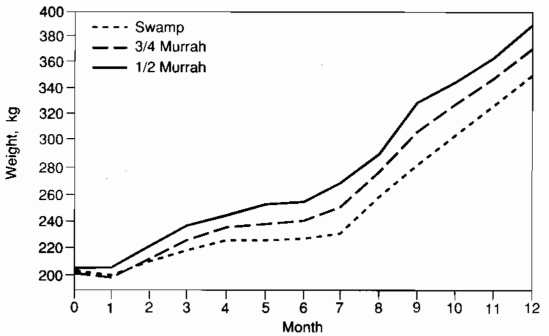


Fig. 2. Growth of buffalo from weaning onwards, for one year at Lumphya Klang Livestock Research and Breeding Center.

III. Draught Ability

Draught ability of swamp buffalo and ½ Murrahs was measured under village conditions. Table 4 shows that, when ploughing on the sandy loam soil, ½ Murrahs generated more draught force than swamp buffalo (33.36 vs 30.62 kg) and ploughed (highly) significantly faster (2.95 vs 2.60 km/hr). In terms of draught power, swamp buffalo generated less power than ½ Murrah ($P<0.01$). However, the work output (area ploughed) in 90 minutes was not significantly different between the two genotypes (544 and 552 m^2 for swamp and ½ Murrahs, respectively).

Comparing the physiological responses of the two genotypes after 90 minutes of work, the rise of temperature and of respiration rate seemed to be slightly higher ($P>0.05$n.s.) in swamp buffalo than in ½ Murrahs, while the latter had a greater increase ($P>0.05$n.s.) in pulse rate than the former.

From an engineering point of view, power is the major criterion to measure draught efficiency of animals. In that sense, the findings of this study show a trend for swamp buffalo to work slightly better than ½ Murrahs by producing less power while obtaining the similar work output. Since Thai farmers do not use buffalo longer than 2–3 hours at any one time in village conditions, the difference in work ability between the two genotypes is hardly noticeable. However, more observations are needed to confirm this finding.

Table 3. The effect of sex on means* for growth performance of buffalo from weaning onwards for one year at Lumphya Klang Livestock Research and Breeding Center.

Item		Sex	
		Male	Female
Number of animals		15	15
Initial measurements			
Weight (kg)		193.2[b]	214.5[a]
Heart girth (cm)		140.0	144.4
Height (cm)		108.2	107.3
Length (cm)		100.1	103.4
Final measurements			
Weight (kg)	— actual	367.5	377.3
	— adjusted	376.3	368.4
Heart girth (cm)	— actual	171.0	174.7
	— adjusted	172.1	173.6
Height (cm)	— actual	123.5	121.9
	— adjusted	123.4	122.0
Length (cm)	— actual	127.8	130.5
	— adjusted	128.3	130.1
Daily weight gain (g/d)	— actual	478	446
	— adjusted	473	451

* Mean in the same row with different superscripts are significantly different ($P < 0.05$)

Conclusion

The growth performances of the ¾ Murrahs and the ½ Murrahs were generally better than those of the swamp buffalo and Murrahs. So far as phyiological traits were concerned, the results were equivocal. Swamp buffalo tended to have lower heart rates (not significant) but higher respiration rates and rectal temperatures than crossbreds (not significant). In terms of draught ability, swamp buffalo were more efficient than the ½ Murrahs but, working under village conditions, this difference is not likely to be noticed.

The results presented here need to be confirmed by further investigations. It would also be appropriate to extend the work to include production costs, carcass evaluation and meat quality of these genotypes under conditions of management aimed at the meat market.

Table 4. Means (± SD) for draught ability and physiological responses of swamp buffalo and ½ Murrahs. Soil type: sandy loam.

Item	Swamp	½ Murrah	P
Environmental measurements			
Ambient temperature (°C)		25.9 ± 3.07	
Black Globe temperature (°C)		28.0 ± 4.11	
Relative humidity (%)		89.1 ± 5.53	
Draught ability			
Live weight (kg)	408 ± 17	414 ± 36	ns
Draught power[1] (kW)	0.21 ± 0.06	0.26 ± 0.04	**
Draught force (kg)	30.62 ± 10.21	33.36 ± 6.60	ns
Ploughing speed (km/hr)	2.60 ± 0.31	2.95 ± 0.29	**
Area ploughed in 90 mins (m^2)	544 ± 163	552 ± 160	ns
Physiological responses			
Δ Rectal temperature °C	1.49 ± 1.07	1.22 ± 1.08	ns
Δ Pulse rate per min	12.36 ± 11.90	15.54 ± 11.60	ns
Δ Respiration rate per min	22.36 ± 14.05	21.00 ± 15.88	ns

Notes: 1) $$\text{Draught Power (kW)} = \frac{FV}{1000 \times 3.6}$$

where F is draught force (kg), V is speed (km/hr) and kW (kilowatt)

Δ is the increase in physiological response after 90 minute work

Utilisation of Feedstuffs by Swamp, Murrah and Crossbred Buffalo

Z.A. Jelan[1] and Norhani Abdullah[2]

Abstract

Crossbred buffalo, which differ in chromosome make-up from swamp and Murrah buffalo, are believed to possess different production potentials which could be exploited for meat production and draught power. It is also possible that these genotypes may exhibit some differences in certain aspects of digestive physiology and efficiency in feed utilisation. This paper reports a series of studies on growth, nutrition, feed utilisation and some rumen fermentation characteristics of different buffalo genotypes. Studies on growth indicated that the ¼ and ¾ swamp buffalo were significantly superior in growth rate and had larger heart girth and greater height at the withers than the swamp type. Though not significant, the crossbreds showed greater feed intakes than the swamp buffalo. Generally, there were no marked differences among the genotypes in the rumen parameters measured nor in feed utilisation.

CROSSBREEDING the swamp with the larger river buffalo began in 1950 but, due to poor interest in buffalo farming and management, an organised crossbreeding program was not practiced. However, recently crossbreeding has been encouraged in order to improve meat and milk productivity and draught power. Several studies (Fisher and Ulbrich 1968, Bongso and Jainudeen 1979, Bongso et al. 1984) have shown that the F_1 hybrid with 49 chromosomes was found to be fertile. Inter se matings of the F_1 hybrids and backcrossing these hybrids with either of their parents have also produced hybrids of different chromosome make-up (Harisah 1988). Differences in genotype and chromosome make-up would be more common on farms where uncontrolled matings occur. Even though few experiments have been conducted to assess the effect of crossbreeding, these crossbred buffalo are believed to possess different production potentials.

This paper reports an investigation on the growth and feed utilisation of various buffalo genotypes, including crossbreds, in a controlled farming and management system. The main objective of the study was to determine the relationship between chromosome make-up, feed utilisation and growth in order to identify a suitable crossbred for a particular purpose; e.g. for meat production and draught.

[1] Department of Animal Sciences
[2] Department of Biochemistry
Universiti Pertanian Malaysia, Selangor, Malaysia

Material and Methods

Growth rate studies

Based on breeding records and karyotype analysis, three groups of 12 month old buffalo, each consisting of six swamp, six ¼ swamp (Murrah × [Murrah × swamp]) and six ¾ swamp (swamp × [Murrah × swamp]) types were used in a growth experiment lasting 30 weeks. The average body weights of these animals at the begining were: 200, 240 and 225 kg respectively. They were penned individually with individual feeding and drinking facilities. The buffalo were obtained from the University's buffalo farm. They were weaned at six months of age and were raised on improved pasture prior to the trial.

The buffalo which had an average body condition score of 3–4 (maximum score 6) were dewormed and vaccinated against foot and mouth disease and haemorrhagic septicaemia prior to the trial.

The animals were fed at 0900 hours and 1400 hours with a basal diet comprising (dry matter basis) 80% solvent extracted palm kernel cake (PKC) and 20% cut-and-carry grass (*Setaria kazangula* and *Brachiaria decumbens*). In addition, all animals were offered 150 g/d of local fishmeal. Body weight (BW) was measured biweekly. Feed intake was measured on two occasions, each of three weeks duration. Measurements of height at withers, height at sacral crest and heart girth were made at intervals of four weeks.

Nutrient degradation and rumen fermentation.

Four swamp and four ¾ swamp buffalo of average age 14 months and 250kg body weight were each cannulated at the rumen (Jelan 1985) and fitted with a permanent rubber cannula (Macam Rubber Pty Ltd, Australia). They were individually penned, managed and fed rations similar to animals in the growth trial. After an adaption period of about 4 weeks the following studies were carried out:

Degradation of feed in nylon bags. Four bags containing standard PKC and four bags containing standard grass samples (*Setaria splendida*) were suspended in the rumen of each cannulated animal. At 24 and 48 hours two bags of each standard sample were removed, washed and the amount of dry matter (DM) and organic matter (OM) degraded were calculated (Mehrez and Orskov 1977).

Comparison of fermentation characteristics. Rumen samples were aspirated through a stainless steel tube permanently attached to the cannula at intervals of 3,6,9,12,15, and 22 hours after feeding. Rumen fluid from each animal was pooled and stored frozen in McCartney bottles pending analyses. Fluid was thawed, centrifuged and analysed for ammonia and total fatty acid concentrations.

Feed utilisation

Twelve buffalo bulls, aged 30–40 months, comprising four each of swamp, Murrah and F_1 crossbreds were individually penned in a trial of 16 weeks. These animals were obtained from the University's buffalo farm and had been raised on improved pastures. Prior to the experiment, all animals were dewormed and each was fitted with a rumen cannula. They were fed solvent extracted PKC ad lib. and a commercial mineral supplement.

Following an adjustment period of about eight weeks, feed and total water intakes were measured for eight weeks. Evaporative water loss from individual drinking bowls was deducted from the total daily water intake. Rumen fermentation was monitored at 3,6,12 and 24h after feeding. Samples of rumen fluid were stored, prepared and analysed as was done previously. All data were analysed with an analysis of variance program using a Statistical Analysis System (SAS) computer program (SAS 1979).

Results

Growth rate studies

The growth responses of buffalo to the improved diet are shown in Table 1. The growth rates of ¾ and ¼ swamp buffalo were significantly different ($P<0.05$) from those of the pure swamp buffalo. Between the crossbreds, the ¼ swamp showed the fastest growth although not significantly different from that of the ¾ swamp buffalo.

The average changes in body measurements are also shown in Table 1. The changes in heart girth, height at withers and height at the sacral crest were parallel to changes in body weight and the levels of statistical difference are indicated in the table.

Table 1. Average growth rates (g/d) and changes in body measurements (mm/week) at specific parts of the body.*

Genotype	Growth rate	Heart girth	Withers	Sacral crest
Swamp	755.5^a	6.3^a	3.9^a	4.2^a
¾ Swamp	786.3^b	8.8^b	5.5^b	4.9^a
¼ Swamp	840.4^b	11.1^c	5.2^b	7.4^b

* Within columns numbers with different superscripts are significantly different ($P < 0.05$)

Table 2 shows the average daily feed intake by swamp buffalo and its crossbreds. There were no significant differences either in DM and or in OM intake among the genotypes although the 3/4 swamp buffalo seemed to utilise more DM and OM than the other genotypes.

Table 2. Average daily feed intake (g/$BW^{0.75}$) of buffalo fed a palm kernel cake and grass based-diet.

Buffalo genotype	Dry matter	Organic matter
Swamp	138.2	132.9
¾ Swamp	146.1	142.8
¼ Swamp	144.7	138.3

Degradation of nutrients and rumen fermentation

The degradation of standard samples of grass and PKC from nylon bags suspended in the rumen of swamp and ¾ swamp buffalo for 24 and 48 hours is shown in Table 3. The degradation of DM and OM from the nylon bags was not significantly different between genotypes.

Table 3. Degradation of nutrients (%) from nylon bags suspended in the rumen of swamp and ¾ swamp buffalo crossbreds.

Genotype	Grass		PKC	
	Dry matter		Organic matter	
	24h	48h	24h	48h
Swamp	35.8	44.5	58.8	68.5
¾ Swamp	34.3	46.8	57.9	65.8

Table 4 shows some characteristics of the fermentation of feed in two genotypes. There were no significant diferences between them with respect to the total volatile fatty acid production (TVFA), rumen pH and rumen ammonia concentrations on a diet based on PKC and grass. However, a generally higher level of TVFA was detected in the crossbreds.

Table 4. Characteristics of the rumen of buffalo fed a PKC and grass based-diet.

Genotype	TVFA (moles/L)	Rumen ammonia (mg/L)	Rumen pH
Swamp	148.8	122.2	6.2
¾ Swamp	153.5	118.7	6.2

Feed utilisation

Table 5 shows the feed and water intake of swamp, river and F_1 crossbred buffalo fed a PKC-based diet. There was no significant difference in DM intake among the three buffalo genotypes. However, greater DM intakes were observed in the Murrahs and hybrids than in the swamp buffalo. A significantly greater ($P < 0.05$) total water intake was observed in the swamp as compared to the crossbreds. However, greater total water intake was also observed in the Murrahs as compared with the F_1 buffalo even though this difference was not statistically different.

Table 5. The mean (± SD) for body weight, feed and total water intake (g/100 kg body wt) by swamp, Murrah and F_1 crossbred buffalo.

Attribute	Swamp	F_1	Murrah
Body wt (kg)	237.0 (25.4)	362.0 (90.6)	273.5 (6.4)
DM intake	1.7 (0.3)	1.8 (0.2)	1.8 (0.4)
Water intake*	5.9 (0.6)^{a}	4.1 (0.9)^{b}	4.9 (0.8)^{ab}

* Within this row numbers with different superscripts are significantly different ($P < 0.05$)

Table 6 shows some rumen parameters in buffalo fed a PKC-based diet. The data were limited and tests for statistical differences were not made. The rumen ammonia concentrations and pH were higher in the crossbreds and Murrahs than in the swamp buffalo. The propionate concentration was greater in the swamp while the acetate and butyrate concentrations were similar among the genotypes.

Table 6. Average daily rumen pH, ammonia and molar proportions of volatile fatty acids in swamp, Murrah and F_1 crossbred buffalo.

	Swamp	F_1	Murrah
Rumen pH	5.4	6.0	6.3
Rumen ammonia (mg/L)	81.0	130.0	123.0
Acetate (%)	32.2	34.6	30.6
Propionate (%)	35.2	23.0	25.4
Butyrate (%)	24.2	26.6	27.2

Discussion

Information on the growth potential of various genotypes of crossbred buffalo of different chromosome number is limited. One of the most important constraints in studies involving buffalo genotypes has been the limited availability of crossbred animals of known breeding history and with similar body condition.

This study showed that crossbreds have significantly greater growth potential than the pure swamp buffalo, particularly on a high plane of nutrition. The larger size of the crossbred, as indicated by larger girth and greater height at both withers and sacral crest (Table 1) is an important trait. These animals may generate greater draught power than the swamp buffalo.

The faster growth rate of the crossbreds required a higher nutrient intake than that of the swamp buffalo of similar age (Tables 2 and 5). We are unable to conclude that there were any differences among the genotypes with respect to digestive physiology. It is unlikely that differences exist among them because there were no differences in DM and OM losses from feed samples in nylon bags suspended in the rumen; nor were there any differences between them in efficiency of rumen fermentation (Tables 3 and 4).

The lower total water intake seen in the F_1 crossbreds than in the swamp type and the Murrahs is not understood. It is possible that there are differences in their ability to regulate body temperature.

The fermentation patterns shown in Table 6 provide some evidence of possible differences between the genotypes when fed a PKC-based diet. Further study in this area, using a larger number of animals, is desirable.

It may be concluded from this study that the ¼ swamp buffalo (i.e. ¾ Murrah) is superior for growth to the swamp type and may be useful as a draught animal. However, the genetic potential of these animals can only be expressed when their nutritional requirements are met.

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Genetic Diversity and Sustainable Agriculture — Implications for Animal Production Systems

R.K. Munro* and D.B. Adams*

Abstract

Genetic selection of domestic animals can lead to a reduction in genetic diversity through the elimination of individuals or populations deemed to be undesirable. Genetic diversity is the basis of population change through selection or crossbreeding and any reduction in that diversity reduces the potential for future genetic change.

Genetic change may be required in the future because of changed demands for produce or because of environmental changes such as climatic change, or reduced availability or effectiveness of inputs to the agricultural system; e.g. fossil fuels, fertilizers and chemotherapeutics. The preservation of genetic diversity would increase the chances that those genotypes would exist or could be selected for.

Maintenance of genetic diversity in live animal populations carries penalties to productivity compared with a population of selected stock. This has implications for profitability of enterprises, generation of capital for national development and trading relationships. Cryopreservation of genetic material, where this is possible, also has costs related to the actual procedures and the research and development of techniques. Preserving genetic diversity, therefore, involves direct costs and the costs of opportunities foregone because of allocation of resources to this area. Allocation of resources to these competing demands raises many questions of equity at national and international levels. Programs to improve buffalo genotypes need to consider these concerns to ensure that the resulting changes to agricultural ecosystems are socially, economically and ecologically sustainable.

In their agricultural roles, animals have been subjected to many years of selection for increased productivity with progressive elimination of animals with the least desirable traits. In many instances the gains from this selection have been extremely profitable.

Along with other aspects of man's activities, agriculture is now being appraised in relation to its ecological sustainability. One aspect of the question of sustainability is the desire to preserve genetic diversity in populations of domestic animals, and the implications that genetic selection within agricultural environments holds for this concept. Appraisal of animal production systems, with a view to their ecological sustainability, is a new and pressing challenge and may require changes in approach from the traditional production-oriented ethos. Some departures from traditional approaches are presented in this paper with a view to stimulating constructive discussion of issues.

* Bureau of Rural Resources, PO Box E11, Queen Victoria Terrace, ACT 2601, Australia

The possibility of climatic change raises the possibility of environmental change on a dramatic scale. The changes that would be required in animal production systems to maintain previously existing levels of adaptation and productivity could be equally dramatic. The need for genetic diversity to accommodate those changes may be great.

Other changes to the environments of farm animals, though less dramatic, are already occurring as a result of changing agricultural practices. This paper describes some of the practices that modify the agricultural environment, such as the use of chemotherapeutics, and the interactions these may have with genetic selection in animal production systems. The role of selection in manipulating levels of genetic diversity and the relative suitability of governmental or other institutions for maintaining valuable genestocks are discussed. Various techniques can be used to preserve genetic diversity and the merits of some of these techniques and their relationships with the social and economic environment are explored.

In the context of the present ACIAR projects the important role that the buffalo occupies in the agricultural ecosystems of Asia is recognised. Increased productivity through genetic change of the buffalo population could contribute markedly to the overall productivity from agriculture. In the light of the possibilities alluded to above, it is important that the evaluation of buffalo genotypes, and an understanding of their interactions with the environment, precede or accompany attempts to alter the genetic composition of local genotypes or the management regimes of local production systems. In this way the possibility of increased productivity being achieved and sustained is enhanced.

Animal Production Systems, Selection, and Genetic Diversity

Selection has occurred within the context of specific agro-ecological environments. These environments have often been made more conducive to animal production by improvements to the quality and quantity of feeds, control of disease and reduction in bioclimatic stress. Many animal production systems now use relatively benign and static environments to allow high levels of production and efficiency. There is concern that livestock selected in these situations may lose the ability to adapt to new and probably less favourable environments and, therefore, be less efficient producers under those circumstances.

If production from animals is to be maintained at present levels, then both the suitability of genotype and environment need to be considered. The histories of introduction of 'improved' European livestock to harsh environments, including Australia, have graphically illustrated the consequences of mismatching genotype and environment.

Even where animals have been kept in the regions in which they evolved, their exposure to pathogens and other stressors has often been increased by changes to their environment. Examples are increased stocking density and associated social stress and unfavourable housing related to ventilation and humidity. In many instances the deficiencies of livestock in dealing with their environments have been overcome by vaccines, chemotherapeutics (e.g. antibiotics and anthelminthics) and by careful attention to nutrition and husbandry.

The opportunity to manipulate the environment of livestock may diminish in the future. Development of resistance to chemotherapeutics by parasites is now widespread in many production systems. The ability of future generations to use chemotherapeutics as an aid to production is already compromised and may have severe implications for maintaining high densities of animals in intensive housing systems or other systems, such as irrigated pastures, where exposure to parasite infection is high. Use of vaccines to control parasites is widely practiced and is often effective. However many serious diseases of livestock, such as those caused by blood-borne protozoa, may not be amenable to control by vaccines. In addition, new disease agents can emerge and effective vaccines may not be developed quickly or easily.

There is no guarantee that current standards of nutrition and husbandry will be sustainable in the future. Increasing competition between man and animals for high-quality feed ingredients and restricted availability of financial capital and other inputs to agriculture (e.g. fossil fuels, machinery and fertilizer) may lead to a return to simpler systems of animal production. Strains of animals adapted to high levels of nutritional and other inputs may no longer be the most appropriate. Concerns about real or perceived environmental issues may also create a demand for products from low-input systems.

A further problem that arises from these considerations of matching genotype to environment is how the match should be measured. Existing attitudes would support the use of production data, with high production being equated with suitability. However, the concept of sustainability raises questions about the time scale over which productivity is to be measured. This challenges conventional agricultural science to move from a 'mindset' of short-term gains to a fuller understanding of interactions in the agricultural ecosystem. This understanding should involve soil–plant–animal–atmosphere interactions and extend to the cultural and socioeconomic aspirations of the communities in which the practices occur.

Genetic Diversity and the Use of Chemotherapeutics

A major function of science is to predict the consequences of certain actions or events. In the case of agriculture, most researchers have restricted their predictions to increased output of a particular commodity over a relatively short period. Chemotherapeutics have provided several examples where the full consequences of their application over the long term require further investigation. Issues which require further consideration include:

— immediate gains to productivity, through use of chemotherapeutics, being offset by selection of resistant parasites and ultimate loss of production potential by reduced ability to control resistant parasite populations;

- effects of chemotherapeutics on the resistance of animals to parasites, especially when host resistance is depressed and no longer exerts continuous control on parasite populations which are then only exposed to intermittent control by chemotherapeutics;
- effects of chemotherapeutics on non-target species such as pasture plants and soil micro- and macro-fauna, and the long-term effects on nutrient cycles, soil fertility and predation of free-living stages of parasites.

The long-term productivity of agricultural systems, therefore, requires a sophisticated understanding of the production system, its inputs, outputs and processes. The vast range of ecological niches for animal production and the variety of adaptations of animals and husbandry systems needed to exploit them requires maintenance of genetic and human cultural diversity to support animal production systems.

Preservation of Diversity

There is a need to preserve genetic material from animals able to produce efficiently without the battery of supports currently employed in some production systems. In developed countries, large sections of particular animal industries can be controlled by one management group. In this situation, selection of animals in controlled environments may result in the loss of particular genotypes or particular genes from large parts of the population. The concern is that the loss is irreversible.

In 'developed' countries, the 'improvement' of domestic livestock may have already decreased genetic diversity, largely through reductions in the population sizes of minor breeds and strains and, to a lesser extent, through loss of alleles within breeds subjected to intensive selection. There may now be a need to establish indices and criteria for genetic diversity in domestic animals.

In Australia in the 1970s a government committee reported on the issue of genetic diversity in the Australian poultry industry (Standing Committee of Agriculture 1979a). It concluded that there was sufficient value in the concept to encourage characterisation and cataloguing of poultry breed resources in Australia and maintenance of much greater levels of genetic variety than formerly. Recommendations relating to the use and capacity of import quarantine stations were included to ensure that a flow of genetic material into the country was possible. Other reports have addressed similar issues in other industries in Australia (Standing Committee of Agriculture 1979a,b).

The Role of Institutions in Preservation of Diversity

Equity between generations should influence decisions that may allow the loss of unique genetic material. Loss of genetic material may hamper the ease or the extent to which animal breeders in future generations can adapt their animals to new environments or alter the nature of their products. The role of biodiversity is therefore essentially one of insurance to provide future generations with the greatest array of genetic material possible. As with all insurance, the questions of cost and chance can be raised. Would the cost of preserving genotypes exceed the possible benefits and, if so, would not commercial breeders see this opportunity and ensure they secure the benefits? Questions such as this are easier to answer with the benefit of hindsight. Commercial enterprises do not always survive to realise their long-term plans, nor would they necessarily have sufficient capital or expertise to respond to what could be major problems on a national or international scale. Selection of genotypes that will yield benefits in the future must also carry considerable risk because the nature of future environments is not known.

Responsibility for the maintenance of genetic diversity is communal and should not be assigned to commercial groups which are subject to short-term market forces. Governmental organisations, perhaps multi-national, may be appropriate for financing and managing schemes to maintain genetic diversity in domestic animals. Such schemes may never earn a profit according to contemporary commercial accounting systems. Nevertheless, they would safeguard the long-term wellbeing of animal production systems that contribute to the wellbeing of people and would act to preserve inter-generational equity.

Preservation of Genetic Diversity and Implications for Developing Countries

In many 'less developed' countries environmental manipulation has not occurred to the same extent as in 'developed' countries. Here genetic selection has led to development of regionally adapted strains (land-races) with greater variety and seemingly greater resistance to local environmental stresses than livestock from developed countries. It appears that the bulk of genetic diversity related to this resistance may reside in the animal populations of 'less developed countries'. As the value of these strains to animal industries in 'developed' countries becomes apparent, some interesting questions related to the strategies and equities of preservation will arise.

Preservation of biodiversity in animals is possible by two methods at present, cryopreservation or conservation of live animals.

Cryopreservation

Cryopreservation (Turner 1981) is the name given to a range of techniques that can be used to preserve living material for long periods at low temperatures. It has some features which make its use convenient and desirable for the preservation of genetic diversity.

1. Cryopreservation has the advantage of maintaining genetic material relatively cheaply, seemingly indefinitely and largely protected from environmental hazards and mutagens such as ionising radiation.
2. Techniques for cryopreservation of male and female germ cells and embryos already exist for a number of species and presumably these techniques could be extended to include others. It is important to note that cryopreservation has been difficult to achieve in some species (e.g. the pig) and substantial research and development may be needed to produce efficient cryopreservation systems for all target species.
3. Genetic material can be acquired from donor animals without the need to remove them from their environment or the breeding population. Local cultural associations with the human population need not be disturbed to any great extent.
4. Problems with equity between 'developed' and 'less developed' countries are not major. The technology can be transferred readily between countries. Collection of material from sources in 'less developed' countries imposes no great cost or disadvantage on those countries. There may be conflict over distribution of benefits that result from the use of genotypes after collection. This possibility should not delay plans for collection of endangered or valuable genotypes but should be resolved as quickly as possible. The prospect of a country having to buy back genes that originated within its indigenous populations would seem to be an undesirable outcome which, if not guarded against, may restrict access of collectors to gene pools.
5. Cryopreserved material is cheaper and easier to transport internationally than live animals. Disease and quarantine problems still exist with cryopreserved germ cells but embryos within their zona pellucida are largely resistant to infection by pathogens and so offer a means for allowing movement of genetic material with much reduced possibility of disease transmission (Shelton and Morris 1985, Bureau of Rural Resources 1989a,b,c).
5. Cryopreserved material can be re-introduced to existing populations of the same species as a source of genetic variation. It can also be used for comparisons with existing live animals to measure genetic changes since collection from that population occurred and it can be used as genetic material free of pathogens that may have infected live genestocks since cryopreservation.

Cryopreservation is, therefore, a valuable tool for preserving genetic material. Without live animal populations though, there seems little likelihood that preserved genetic material can contribute at all effectively to the genes of living organisms. Developments in gene insertion and chimaera technology are possible but seem to be many years in the future. The existence of live animals is therefore vital to the strategy of preservation of genetic diversity. In contrast to wildlife, there is little likelihood of extinction of domestic species. However, until a comprehensive program for cryopreservation of domestic species is a reality, preservation of genetic diversity in this area depends on conservation of live animals.

Conservation of live animals

Live animal preservation can be achieved in situations with minimal human intervention where populations rely largely on preservation of habitat to ensure survival ('lock up' preservation) or where they are maintained in their usual animal production systems and continue to contribute to meeting human needs ('in situ' preservation). In the former situation, yields of animal produce may not be harvested or may be harvested in diminished amounts because of reduced or absent management and husbandry inputs. Each of these arrangements has biological and socio-economic characteristics which may be advantageous under certain circumstances.

'Lock-up' preservation, with the low level of managerial intervention that this implies, brings with it the possibility of continuous adaptation of animal populations to changing environmental pressures. It has the advantage of low maintenance costs but also the disadvantages of high establishment costs and high opportunity costs due to committed and inflexible resource allocation which may not be maintained during periods of short-term crisis.

'In situ' preservation has the advantages of low establishment costs and continued contribution to the wellbeing of the human population. In this situa-

tion there is some motivation to maintain the preservation because of the immediate benefits. However, there is also motivation to introduce 'improvements' to increase these benefits. This is of course the beginning of the process perceived to reduce genetic diversity and generate the need for preservation. It also serves to demonstrate some of the problems of equity that may arise from policies of in situ genotype preservation, namely:

— there will be reduced options to increase productivity by changing husbandry and management procedures, by using other aids to productivity such as chemotherapeutics and selecting superior stock from the group for propagation;

— it will mean accepting lower levels of productivity in the hope of long-term gains because of

  (i) lower productivity which will contribute to lower standards of living, less opportunity for investment, development and social progress, perceptions of inefficiency and low social worth and a need to provide some form of compensation or recognition of the benefits foregone for the common good; and

  (ii) gains which may never eventuate, which may not be justified in light of the productivity foregone or which may not be of benefit to those who have borne the cost but may be of greater benefit to those who have created problems in other places.

Perceived benefits flow from the preservation of genetic diversity but many disincentives may apply to those engaged in preservation. These disincentives could be diminished by the purposeful creation of circumstances in which the existing custodians of genetic diversity could continue their stewardship of that diversity profitably and without disadvantage. One approach may be to retain and foster animal production over a wide range of environments as an effective method for promoting genetic diversity. Unhappily, this attractive option has potentially serious drawbacks. Without aids to production such as chemotherapeutics, exotic feedstuffs and exotic genotypes, or compensatory affirmative action, those regions of the world not capable of efficient animal production according to current commercial concepts would be disadvantaged. Other regions which are currently efficient in these terms would be able to compete to the detriment of local producers, local industry and local genotypes and their supporting cultural systems. Affirmative action to protect local markets is important in retaining local production and should be considered an integral part of maintenance of genetic diversity in farm animals.

There is a need to understand how an animal population is maintained and how husbandry is shaped by the socio-economic environment. Social and economic factors may be as important as the agricultural and genetic considerations which bear upon productivity and genetic diversity.

Conclusion

It appears from this appraisal that the issue of genetic diversity involves many aspects of the agricultural, social, economic and trading arrangements of nations. There is wide scope for thought in addressing the perceived and demonstrated need for stewardship of the genetic resources present in the world's domestic livestock and their near relatives. Attempts to improve the productivity of agricultural systems through introductions of new genetic material into local buffalo populations or genetic selection, need to be evaluated in terms of their long and short term effects on buffalo performance and the productivity of the ecosystem as a whole.

Present attitudes to genetic improvement may need to be reviewed in light of concerns over sustainability of animal production and the need to maintain a level of genetic diversity. The direct costs of maintaining a level of diversity, and the indirect costs of productivity foregone need to be assessed when determining what level of genetic diversity is desirable in animal production systems. Justifying the diversion of resources to genotype preservation from other pressing social and environmental problems, especially in less developed countries, also requires careful consideration. Many issues impinge on the challenge to maintain genetic diversity. Wise decision-making requires that all of them should be considered.

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International Assistance for Buffalo Research: has enough been done?

B.M.A.O. Perera*

Abstract

International support for buffalo research over the past two decades has resulted in substantial strengthening of national institutes in many Asian countries, both materially and intellectually. The agencies which have played leading roles include the Food and Agricultural Organisation, the International Atomic Energy Agency, the Australian Centre for International Agricultural Research, Deutsche Gesellschaft für Technische Zusammenarbeit, the Canadian International Development Research Centre and the Swedish Agency for Research Cooperation. The support has been of three main types: a) infrastructure development involving provision of equipment, training and expert services, b) funding of specific research projects to enhance knowledge on biology and productivity to solve problems which limit productivity, and c) promotion of information interchange. Although much of the knowledge needed to improve buffalo production through breeding, feeding, management and disease control now exists, there is a clear need to study applications at the village, small-farm level for improving productivity through practical, cost-effective and sustainable interventions. This requires a sound understanding of the target farming systems, a multidisciplinary approach, collaboration with livestock extension services and interaction with national development programs. Agencies which fund research, as well as institutes engaged in it, have an obligation to ensure that their efforts result in tangible benefits to the rural buffalo farmers.

SUBSTANTIAL support has been provided by international, bilateral and national funding agencies, particularly over the past two decades, towards improvement of buffalo production in Asia (Acharya and Lokeshwar 1989). The main objective has been to promote more efficient utilisation of the buffalo for agricultural production in village farming systems, thereby contributing to improvement of the socio-economic status of the small farmers. The basis of this support has been a firm conviction, within national governments as well as among international funding agencies, that the buffalo has an important role to play in the agricultural economies of most developing countries in Asia.

The water buffalo plays different roles in different countries, providing milk, meat, draught power and social security in different combinations and proportions. There are only two major types of buffalo (river and swamp) but they are reared in vastly differing environments and under a multitude of management systems. Therefore, in any attempt to improve buffalo production, the initial need is to identify the constraints to optimal productivity in each specific management system and to determine the areas where research is needed to overcome these constraints. The type of applied research needed to address these problems is certainly not easy to conduct. It calls for a sound understanding of the target farming system, requires an interdisciplinary approach and must judiciously combine empirical on-farm studies with advanced laboratory techniques. The ultimate aim should be to develop cost-effective interventions based largely on indigenous resources.

The objective of this paper is to summarise the type of support which has been given to water buffalo research and development in Asia through different international and bilateral funding agencies and to highlight some of the areas where useful research results have been generated. It also attempts to identify the reasons for the paucity of on-farm applied research which is required for translating the knowledge already available into meaningful field applications. The focus of the paper will be on the process and modalities of research support, rather than on specific areas or scientific disciplines in which future research is required.

* Animal Production and Health Section, Joint FAO/IAEA Division, International Atomic Energy Agency, PO Box 100, A-1400 Vienna, Austria

Past and Present Support

Food and Agricultural Organisation (FAO) Rome

FAO has been active in supporting livestock production in tropical Asian countries since the early 1950s. Specific attention to buffalo production, however, gained momentum only in the early 1970s, in response to recommendations emanating from several of its expert consultations. During this period there was much interest in establishing an International Buffalo Research and Development Centre and several Asian countries were in support of the idea. However, in the mid-1970s an FAO expert undertook a survey of buffalo production in seven Asian countries and, based on the finding that many of the countries had established national research and development programs of their own to improve buffalo production, recommended that the strategy should be to strengthen national centres and to link them through a regional network.

The main mechanisms through which FAO supports buffalo research are Technical Cooperation Projects (TCP) which are country-specific, and regional programs. One of the earliest TCPs was a cattle and buffalo development and extension project in Pakistan, initiated in 1974, for improving breeding techniques and extension services under rural conditions. The studies conducted under this project and those undertaken concurrently in India have enabled the development of semen freezing technology for the buffalo (Hultnaes 1972). The benefits have clearly transcended national boundaries and facilitated wider application of Artificial Insemination (AI) throughout the region in this species.

A second major undertaking was the strengthening of the Philippine Carabao Research and Development Centre, financed by UNDP. This project was initiated in 1981 and had several components, the main activities being aimed at improving the milk production of carabaos through crossbreeding with the river types, evaluating the suitability of different genotypes for use as milk, meat and draught animals under different management conditions, and studying various aspects of reproduction, management, nutrition and diseases (Ranjhan et al. 1987).

FAO has also assisted in the compilation and dissemination of information on the buffalo. An important early contibution was to assist Dr Ross Cockrill in the publication of his pioneering book on the buffalo (Cockrill 1974). With assistance from the Swedish International Development Agency (SIDA), FAO organised an international meeting on reproduction of buffalo in Karnal, India, in 1978 and published the proceedings (FAO 1979).

In 1983 a UNDP-funded regional project entitled 'Buffalo Development — Technical Cooperation among Developing Countries for Training Junior Scientists and Dissemination of Research Results and Technology' was initiated. Under the first phase of this project three training courses were conducted: (a) Technical and economic aspects of agro-industrial by-product utilisation (Sri Lanka and India) (b) smallholder buffalo production systems (Philippines) and (c) Clinical aspects of buffalo reproduction (Pakistan). Three compendia of research results and state-of-knowledge reports were compiled in each of the subject areas and were published by the International Buffalo Information Centre (IBIC) in Bangkok.

The concept of Technical Cooperation among Developing Countries (TCDC) was utilised to good advantage through this program, much of the local costs being met by the participating countries through the National Currency Fund (NCF) established under FAO's Animal Production and Health Commission for Asia and the Pacific (APHCA). Phase two of this project was aimed at strengthening the regional network of buffalo development centres in Asia and included three training workshops, study tours, extension demonstrations and the writing of monographs.

FAO organised a Roundtable on International Cooperation in Buffalo Research and Development at the Second World Buffalo Congress held in New Delhi, India, in December 1988 (Acharya and Lokeshwar 1989). Arising from the recommendations of this meeting, an International Network has been initiated and steps are being taken to secure core funding for supporting participating institutes to undertake specific research projects.

International Atomic Energy Agency (IAEA) Vienna

The Joint FAO/IAEA Division's Animal Production and Health Section has been supporting research on ruminant production in Asia since the early 1970s, and buffalo production specifically since 1978. The Section's research programs are aimed at solving problems which limit animal productivity in tropical and subtropical regions, with emphasis on improving nutrition, reproductive efficiency and health of livestock. Particular emphasis is placed on evaluating the productivity of indigenous and upgraded breeds, under traditional village-level or small-farm management systems, with the objective of devising simple, cheap and acceptable methods for overcoming constraints imposed by climate, management, nutrition or diseases (Dargie 1989).

In order to provide technical support for these activities, a laboratory was established at the FAO/IAEA Agricultural Laboratory in Seibersdorf (near Vienna), with facilities for development and adaptation of nuclear and related techniques which can be applied under conditions prevailing in developing countries. For example, standardised kits for progesterone measurement, based on a simple and robust RIA method, are currently being supplied to over 70 laboratories for studies on reproduction. Similarly, development work is being undertaken in collaboration with leading laboratories of the world for standardising ELISA kits for detecting antibodies and antigens associated with a variety of viral, bacterial and parasitic infections. Several of these (e.g. for rinderpest, brucellosis and trypanosomiasis) are now being distributed to institutes participating in FAO/IAEA projects. The laboratory also serves as an important training facility for counterparts in developing countries wishing to establish the above techniques.

The FAO/IAEA provides support to institutes in developing countries through Coordinated Research Programs (CRPs) and Technical Cooperation (TC) projects. The CRP scheme involves the award of research contracts to scientists to conduct specific research projects of relevance to the objectives of that particular program. The contract holders are provided with modest financial support for equipment, reagents and local costs. They also have access to standardised kits, technical advice and literature services from the Joint FAO/IAEA Division. The participants are brought together for Research Coordination Meetings (RCMs) which are held every 16–18 months to promote interchange of information. At these meetings the contract holders have the opportunity of discussing their work and future plans with resource persons (termed 'agreement holders') who have specific expertise in the area.

There have been two successive five-year CRPs dealing exclusively with the buffalo. The first phase of this program, entitled 'The Use of Nuclear Techniques to Improve Domestic Buffalo Production in Asia' (1978–84) included 12 contracts from 7 countries (Bangladesh, India, Indonesia, Malaysia, Philippines, Thailand and Sri Lanka), and 4 agreements from 2 countries (Australia and Sweden). Four RCMs were held during this period and the papers presented at the final RCM, together with the conclusions and recommendations, were published as an IAEA Panel-Proceedings Series in 1984 (IAEA 1984). The second phase of the program (1984–89) had 14 contract holders from 8 countries (Bangladesh, Indonesia, Malaysia, Pakistan, Philippines, Thailand, Sri Lanka and Vietnam) together with 5 agreement holders from 4 countries (Australia, Japan, Malaysia and Sri Lanka). Three RCMs were held, and the proceedings of the final RCM were published in 1990 (IAEA 1990).

Within the framework of the IAEA's TC program, the Joint FAO/IAEA Division assists Member States to become more self-reliant by strengthening the capability of institutes within the country to conduct studies on problems facing livestock production. The assistance provided includes equipment, training of local staff and provision of expert services in specific areas of need.

Several TC projects in Asia have dealt exclusively with buffalo, or with large and small ruminants in general. In Sri Lanka two successive projects were implemented (1978–86) for strengthening facilities at the University of Peradeniya and at the Veterinary Research Institute for research on nutrition, reproduction and diseases. The research projects undertaken within this framework also received support from other donor agencies such as SAREC (Sweden) and ACIAR (Australia).

The studies on reproduction provided comprehensive information on effects of climate, management and nutrition on reproductive efficiency of buffalo under village conditions (de Silva et al. 1985, Perera 1987). A management strategy, involving restricted suckling of calves, was found to be effective in reducing the long period of postpartum anoestrus which is responsible for poor fertility in village buffalo. The nutritional studies provided information on mineral deficiencies occurring in different forages during different seasons of the year, and also resulted in the development of a practical method for improving the feeding value of rice straw through urea treatment (Jayasuriya and Karunaratne 1984). Studies on *Toxocara vitulorum*, a parasite causing heavy mortality in buffalo calves, provided the basic information needed for devising a practical method of controlling the parasite (Roberts 1990). It involves the use of a single dose of a cheap and readily available anthelmintic at the most appropriate stage; this is now being applied in many other Asian countries where the parasite is a major problem.

In Thailand, the University of Khon Kaen was provided with assistance to establish an RIA laboratory and to apply this technique in studies on village buffalo reproduction. The facilities for nutritional studies were also upgraded and several staff members were trained in these disciplines. Currently the Joint FAO/IAEA Division is operating a multidisciplinary TC project funded by the UNDP, involving studies on soils, plants and animals. The components in animal science have assisted several universities (Chulalongkorn, Kasetsart, Chiangmai and Khon Kaen) as well as the Department of Livestock

Development to strengthen their research capabilities in reproduction and disease diagnosis. Studies on reproductive endocrinology have yielded valuable information which is now being used for improving fertility under small-farm conditions (Kamonpatana et al. 1989).

The Joint FAO/IAEA Division is also implementing a UNDP country project in Indonesia, aimed at improving the capability for studies on interactions between nutrition and reproduction of ruminants and at establishing ELISA techniques for diagnosing the more important diseases of livestock. The recipient institutes are the National Atomic Energy Agency (BATAN), the Directorate General of Livestock Services (DGLS) and the Research Institute for Animal Diseases (BALITVET). Based on the studies undertaken at BATAN, a strategy has been developed for providing cheap supplementary feeding to cattle, buffalo and goats, in the form of multi-nutrient urea-molasses blocks (UMB). Field trials have shown that UMB supplementation increases production (growth, milk) and reproduction in animals fed low quality roughage diets in a cost-effective manner (Dargie 1989). The technology for making the blocks has been simplified so that it can be adapted to local conditions and, in collaboration with the DGLS and Provincial Directorates of Livestock Services, BATAN is now transferring the technology to village farmers.

In the animal disease component of this program a national training course was held on the use of ELISA for diagnosing brucellosis. The Regional Disease Investigation Centres of the DGLS have been provided with the necessary resources for using this technique for epidemiological studies aimed at formulating a national control policy for brucellosis.

In the Philippines, a project was supported to evaluate the productivity of village carabaos maintained under traditional conditions and to monitor the effects of changes in management, nutritional supplementation and improved health care. The participating institutes are the Philippine Nuclear Research Institute, the Bureau of Animal Industry, the University of the Philippines at Los Baños and the International Institute for Rural Reconstruction.

The Universiti Pertanian Malaysia was provided with assistance to establish RIA techniques for hormone measurement and to use nuclear and related techniques for studies on utilisation of agro-industrial by-products as animal feed. Studies conducted under this program have indicated methods for improving reproduction of buffalo by strategic weaning of the offspring (Jainudeen et al. 1983) and for using palm-press fibre (waste from the palm oil industry) for feeding ruminants. A further component of this project is a collaborative attempt between the University and the Department of Veterinary Services (DVS) to establish ELISA techniques for diagnosing important diseases of livestock. This will enable the UPM, DVS and the Veterinary Research Institute at Ipoh to undertake epidemiological studies on diseases such as brucellosis and to use this knowledge for formulating more effective control programs.

In Vietnam a program to strengthen capability for studies on reproduction of cattle and buffalo is underway at the Institute for Agricultural Technology in Ho Chi Minh City. Studies have been initiated to evaluate reproductive efficiency in different grades of crossbred buffalo (swamp × river) and cattle (indigenous × European), with the objective of determining the best genotypes for use under local conditions. Assistance is also being provided to establish ELISA techniques for diagnosis of livestock diseases (trypanosomiasis in cattle and buffalo, and pseudorabies in swine) at the National Institute for Veterinary Research in Hanoi and the Veterinary Research Institute in Ho Chi Minh City.

Australian Centre for International Agricultural Research (ACIAR) Canberra

ACIAR promotes research into improving agricultural production in developing countries, by mobilising Australian expertise to help developing countries to identify and solve problems through collaborative research programs. It contracts research groups in Australian institutes to work with partners in developing countries and provides supplementary support to complement the resources of the participating institutes.

Two successive projects were supported in India (1982–89) on increasing the efficiency of straw utilisation through the use of urea-molasses blocks (UMB). The response to supplementation has been spectacular in terms of improved growth and milk production and the technology is now being used on a wide scale by village farmers in several dairy cooperatives. A third project is currently underway to study the feasibility of incorporating anthelmintics in the UMB, thus providing a practical delivery system to control gastro-intestinal parasites in milking buffalo at the same time as providing supplementary nutrition. A project in Thailand (1984–88) examined chemical and physical characteristics of fibrous agricultural residues under different environments and looked at supplementation strategies for the different materials.

The two projects on genetics and breeding, which are being concluded at this workshop, have followed the structure of CRPs referred to above, with several participating countries tackling a common problem. The project on evaluation of different buffalo genotypes for draught, meat and milk production (1985–90) was aimed at encouraging research institutes in Southeast Asia to undertake comparative studies on different breeds and/or strains of buffalo in respect of nutrition, reproduction, growth and draught power. The program on genetic identification of strains and genotypes of buffalo and goats in Southeast Asia (1986–90) involves the analysis of patterns of inheritance of biochemical markers and chromosomal segregation in different river × swamp crosses.

A multidisciplinary project on studies of draught power systems is underway in Indonesia (Hoffmann et al. 1989). The three main components are farming systems research, nutrition-physiology and economics. On-site farm trials, ploughing contests, demonstrations and training of farmers in new technologies are part of the activities aimed at improving draught power output from swamp buffalo and its optimum utilisation by the village farmers.

In the field of animal diseases, a regional program is underway to establish improved methods for the diagnosis and control of livestock diseases in Southeast Asia using the ELISA technique. The buffalo diseases of importance for which ELISAs are being established are brucellosis and haemorrhagic septicaemia (HS). In the case of brucellosis the ELISA is being tested against conventional methods for use in sero-epidemiological surveys, while the objective of the HS work is to develop a typing ELISA for identifying HS-causing strains of *Pasteurella multocida* from field isolates (Dawkins et al. 1990).

A project on epidemiology of ephemeral fever in China has introduced new diagnostic techniques to study the epidemiology of this disease. In Sri Lanka, a project funded jointly by ACIAR, IAEA and SAREC to study the life cycle of the important helminth parasite *Toxocara vitulorum* yielded valuable information which was then utilised for developing an effective control strategy (see IAEA above). A second project in Sri Lanka looked at the feasibility of using vaccines for babesiosis and anaplasmosis in ruminants.

In Thailand support was provided for developing modern diagnostic methods for foot-and-mouth disease (FMD). The techniques established permit identification of the serotypes involved in an outbreak and therefore allow more rational vaccination strategies to be adopted.

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) Bonn

GTZ is the organisation responsible for Technical Cooperation activities in the (former) Federal Republic of Germany. It has supported two major livestock development projects involving buffalo. The first, located in the Punjab District of Pakistan (1978–81) aimed at improving livestock production through initial surveys and subsequent studies on fodder production, AI, animal health services, milk marketing and use of male calves for meat production.

A follow-up project (1983–89) is located at Pattoki in the Punjab and is aimed at establishing economically independent farmers' organisations on a self-help basis, and providing them with improved extension services and marketing facilities. The research component of the project is integrated with the infrastructure development aspects and involves studies on management, nutrition, growth, health and reproduction. In 1987 GTZ sponsored an international symposium on buffalo reproduction in Islamabad and assisted in publication of the proceedings (PARC).

International Development Research Centre (IDRC) Ottawa

IDRC is a corporation funded by the Canadian Government, with an international Board of Governors. Its mandate is to support scientific and technical research by developing countries based on their own priorities. One of the seven Divisions within IDRC is Agriculture, Food and Nutrition Sciences (AFNS), with the objective 'access to food for the individual'.

IDRC is supporting a project, based in Malaysia and involving several Southeast Asian countries, to study the relationship between chromosome composition and production characteristics in different grades of swamp × river crossbred buffalo. In the Philippines, a project was undertaken to study various aspects of draught power, with the objective of providing information on constraints faced by small farmers and designing practical interventions. Two further projects on draught power are being supported in Thailand and India, with more specific emphasis on the role of nutrition, and aimed at evaluating the potential for improving draught power on small farms.

IDRC has supported the International Buffalo Information Centre (IBIC) at Kasetsart University in Thailand since its inception. This has resulted in problems involving actual farming situations because such projects are difficult to execute and control and are of a long-term nature. There is also no guarantee that scientifically valid or statistically significant data which are publishable will be forthcoming from such investigations.

A further constraint is that scientists working in universities or research institutes sometimes have little contact with the field livestock services or national agencies involved in development and extension activities. While it is necessary that any livestock development program should have a research component aimed at monitoring the effects of any innovations that are applied, it is also clearly desirable for scientists to tailor their research around their national or local livestock development programs. The two sectors should ideally work in partnership, complementing the resources and expertise of one another. Donor agencies should promote and, where necessary, make their support conditional on such interaction.

Similarly, different funding agencies working in related fields within a country or a region should attempt to coordinate and link their activities. For example, one agency may be assisting a research institute in the development of techniques for disease diagnosis, while another is supporting the field veterinary services to undertake epidemiological studies. The two projects should obviously work together if the country is to derive the full benefits. Unfortunately, such collaboration is sometimes lacking.

Bridging the Gap

As stated in the introduction, the objective of most funding agencies is to generate research which would ultimately (but not in the too distant future!) help the small farmers of Asia to utilise the buffalo more efficiently for improving their economy. Developing the infrastructure for research in developing countries and providing scientists with the opportunity to play a dynamic role in national development is also an important consideration. However, the ultimate goal should not be clouded by the intermediary processes.

In my opinion, international funding agencies should strive for more coordination between one another for the type of support provided. They should also restrict institution building and limit infrastructure development to countries where a real need and justification exists. More support should be channeled to well-defined projects aimed at solving the problems faced by indigenous farmers. A greater degree of selectivity aimed at focusing support in priority areas and more vigorous technical direction as well as regular critical reviewing of the results is desirable. A proven method of achieving this is to provide for peer-reviews through research coordination meetings or workshops, which also promote interchange of information between scientists working on similar problems within the region.

Attempts should be made to foster interdisciplinary research aimed at tackling a specific problem from various angles and to ensure active interaction with related livestock development programs within the country. Collaboration with other field extension services and farmers' organisations should be encouraged where relevant.

The adoption of a structured approach along the following lines should be promoted in order to ensure that research goals stay relevant to local problems:

a) determine current status of production and the major constraints, through field surveys and longitudinal case studies;

b) study possible methods for overcoming the constraints, using local resources and simple interventions such as strategic supplementation of the diet, changes in management, control of diseases, etc.;

c) test these under local farming conditions and, if found to be effective and applicable, undertake wider dissemination through national livestock development and extension systems.

Admittedly, these are difficult and unpopular choices. However, the agencies which fund research, as well as the institutes engaged in it, have a responsibility to make the best use of available resources, and to ensure that some of the benefits reach the ultimate target, the rural farmers who form the backbone of agricultural production in most Asian countries.

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the development of a valuable repository of information on all aspects of buffalo production, which serves as a focus for formal as well as informal interchange of information. The 'Buffalo Bulletin' published by IBIC is a further contribution in this direction.

Swedish Agency for Research Cooperation with Developing Countries (SAREC) Stockholm

SAREC is an independent agency of the Swedish Government and has the objectives of strengthening research capacity in developing countries and facilitating their access to research results. It supports international, regional and national programs. In the field of buffalo production, SAREC's main support has been to a multidisciplinary program in Sri Lanka.

In 1980 SAREC funded a national workshop on buffalo research to document the present status and future priorities (SAREC 1980). Based on the recommendations, and subject to regular review by Swedish and Sri Lankan scientists, SAREC is supporting a broad-based program of research involving various aspects of management, nutrition, reproduction and diseases of buffalo, as well as studies on socio-economic aspects of buffalo production. Some of these studies have also received supplementary support from projects of the IAEA and ACIAR.

The results from these studies have provided valuable baseline information on buffalo production in Sri Lanka (see also IAEA above). With regard to nutrition, the information required for providing strategic supplementation with minerals, which are deficient in certain regions or during different seasons, now exists. Improvement of reproductive performance has been shown to be possible through improved nutrition and calf management practices such as limited suckling (Perera et al. 1988). Studies on the helminth parasite *Toxocara* (in collaboration with IAEA and ACIAR projects) have yielded the information needed for effective control through strategic use of anthelmintics. With regard to HS, studies on the carrier state and immunity after vaccination have provided more insights into the epidemiology of this disease.

Based on this work, an educational booklet containing information on the biology and husbandry of buffalo has been published (NARESA 1989).

Discussion

From the foregoing it is clear that much international and bilateral support has been channelled to buffalo research in Asia. The inputs from national sources have also been considerable, particularly in countries such as India, Pakistan and Thailand. These investments in infrastructure development have resulted in well equipped laboratories and adequately qualified staff in many Asian countries, with sufficient resources to handle the type of research needed to improve buffalo production under their own conditions.

Support has also been provided for specific research projects to study methods of improving buffalo production and for interchange of information between scientists within the region. The concept of coordinated research programs, woven around a common theme, with several participating countries forming a network has proved popular among donors as well as recipients.

In general, it can be concluded that the approach taken by many international agencies, that of strengthening national research capability and facilitating exchange of information as well as transfer of appropriate technology between developing countries, has served the needs of the region far better than the establishment of a centralised international centre.

Needs for the Future

In most countries of Asia, a considerable wealth of knowledge has been accumulated on the basic physiology and production characteristics of the buffalo. With regard to the dairy-type river buffalo, it can be stated that much of the information needed for improved breeding, feeding, management and disease control already exists. In the predominantly draught-type swamp buffalo, the diversity of environments and production systems precludes generalisations but the basic means to improvement exist.

The question is, how much of this has been tested and applied in real farming situations, and what has been the contribution towards improving production at the village level? Although some of the new knowledge and technologies have been translated into practical applications, my contention is that much more needs to be done in this direction. Even where practical, proven, applications exist mobilisation of appropriate national agencies responsible for dissemination of the technology among farmers has been slow.

There are several possible reasons for this trend. The first is that some research workers, by the very nature of their background and training, may not understand the problem from the farmer's viewpoint, or appreciate the importance of seeking a solution within the socio-economic framework of the farmer. The second is that they are cautious about tackling

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Results from the Buffalo Evaluation Project and Future Directions for Research

J.E. Frisch* and J.E. Vercoe*

Abstract

When this ACIAR project was initiated, we posed a number of questions relating to ways of improving the productivity of the swamp buffalo of Southeast Asia and offered suggestions that might lead to solutions to those questions (Frisch and Vercoe 1984). The solutions offered ranged from being solely genetic to solely environmental. However, the nature of the project was such that emphasis would be placed on genetic solutions while not forgetting most problems would be solved through some combination of both genetic and environmental changes. In the interval since the project was initiated, less than one buffalo generation has passed. It would therefore be extremely naive to think that complete investigation of possible genetic solutions could have been accomplished by project scientists. Nevertheless, it could be expected that the basis for improvement of productivity would have been established and knowledge relating to future directions for research effort would have been accumulated. This paper examines the degree of success achieved by the project in both areas of expectation with success being measured in terms of improvement in the major components of productivity in any country in the region. The desirability of increasing each of these major components has been presented previously (Frisch and Vercoe 1984).

Improvement of Growth Rate

THE relevance of increasing growth rate relates to concurrent increases in draught capacity and the amount of meat produced per unit of time, and to a likely reduction in the age at puberty. Studies within the project have demonstrated that F_1 (swamp × river) animals grow far more rapidly than the pure swamp types. In the Philippines, liveweights of F_1 (carabao × Nili-Ravi) and F_1 (carabao × Murrah) were about 50% higher at 12 months of age than those of straightbred carabao both in village and in institutional herds (Parker et al., these Proceedings). In Thailand, Bunyavejchewin et al. (these Proceedings) have reported that the F_1 (Thai swamp × Murrah) had higher weaning weight and post-weaning gains that were about 26% higher than those of the purebred Thai swamp. Kamonpatana et al. (these Proceedings) have reported consistent differences in growth to three years in favour of the F_1 ranging from 13 to 34% depending on age, sex and location. In Vietnam growth rate to 12 months of age was about 25% higher for the F_1 swamp × Murrah (Cuong and Trieu). In Indonesia (Situmorang and Sitepu, these Proceedings) the liveweight of the F_1 swamp × Murrah was significantly higher at all ages than that of the straightbred swamp both in village and institutional herds. By nine months the F_1 hybrids were about 22% heavier than the straightbreds. By three years of age the difference had increased up to 30%, depending on location, in favour of the F_1 hybrid. There has not been any report from project scientists from any country that contradict these results. Thus, improvements in growth rates of swamp buffalo can be expected over a wide range of environments and management systems simply by crossing to a suitable river breed. That this result has widespread applicability is supported by the absence of any reports of genotype × environment interactions for liveweights at any age. This effectively discounts the possibility that all of the improvements in gains have arisen from favoured treatment of the crossbreds. Thus a substantial genetic improvement in liveweight has been obtained in a single generation using relatively simple technology. To achieve gains of similar magnitude by selection within the swamp types, complex, large-scale recording schemes would have to be organised and then operate efficiently for probably 50 years

* CSIRO Division of Tropical Animal Production, Rockhampton, Queensland 4702, Australia

or more. Even if the lack of recording facilities and small herd sizes are ignored as major constraints to success of such a scheme, the time involved would alone make such a selection program impractical. The evidence is therefore very clear that at least initially, where rapid and substantial genetic improvement of growth rates of swamp buffalo is required, crossing to one of the large river breeds is at present the only feasible solution.

For these experimental results to have a significant impact at the national level, widespread acceptance of the crossbreds by farmers is essential; simple, effective methods for producing large numbers of F_1s must be developed and breeding programs that would ensure continuation of the gains achieved in the initial cross need to be tested. The question relating to the availability of feed for larger, faster-growing animals also needs to be addressed. Results from the project provide clear evidence that at least those farmers participating in the crossbreeding studies have been able to feed their crossbreds at such a level that they have been able to express their higher genetic potential for growth. In all countries the F_1 hybrids were substantially heavier than the swamp types reared under similar conditions. At a more general level, if it is assumed that the production of cereal straws and other agricultural and horticultural by-products is to retain proportionality with human numbers, it is likely that the maximum sustainable mass of buffalo will rise accordingly. Sociological reasons aside, it is likely that there is no biological penalty associated with this mass being composed of fewer, larger animals rather than a larger number of smaller animals, provided levels of feeding remain in proportion to size. In this respect, differences in digestive efficiencies of the swamp types and the crossbreds are likely to be small or non-existent (Jelan and Abdullah, these Proceedings) and results from cattle suggest that, at ad lib. levels of feeding, overall efficiency of feed utilisation by the larger crossbreds will be similar to that of the smaller swamp types (Frisch and Vercoe, 1984). Thus in those situations where an increase in growth rate and size are desirable or necessary, prime consideration must be given to crossing the swamp types to the appropriate river breed.

Improvement of Reproductive Rate

In those countries or regions where increases in numbers of buffalo or increased rates of turnoff are required, increases in reproductive rates of the existing breeds will be necessary. It may be that environmental solutions for increasing the characteristically low reproductive rates of swamp buffalo will be found. However, unless these solutions are very simple, inexpensive and readily available at the village level, they cannot be expected to have any significant impact at the national level on buffalo reproductive rates. The long-term solution, one that does not require continual inputs, is to use genotypes that have higher reproductive rates than the swamp types over a wide range of environmental conditions. The only possible way in which this could be achieved in the short term is by crossing the swamp types to other appropriate breeds or strains. Investigations of this possibility formed an integral part of the ACIAR-sponsored project. Comparative reproductive rates of straightbred swamp, river (either Murrah or Nili-Ravi) and their F_1 hybrids have been measured in several different countries.

To demonstrate statistically significant differences in reproductive rates of the different genotypes in all countries would require comparisons involving hundreds of animals at each location. Lack of resources precludes such a strict comparison. However, data have been obtained for several reproductive parameters that indicate that genetic differences do exist between different buffalo genotypes. In assessing these differences in reproductive performance, it is necessary to know whether genotype × environment interactions occur and if so under what conditions. It was with this aim that calving to conception intervals were measured in Sri Lanka on two groups of Lanka and Murrah buffalo, one group allowed to graze natural vegetation and the other allowed to graze but offered additional supplementary feed (Mohamed and Jayaruban, these Prodeedings). Both genotypes responded markedly to the supplementary feed with reduced calving to conception intervals but, more importantly in the context of long-term improvement of the reproductive rate, the calving to conception intervals of the Lanka buffalo that were grazed and not offered supplementary feed were the same as those of the Murrah group fed concentrate supplement (214 + 104 and 214 + 116 days, respectively). This indicates that a real genetic difference in reproductive capacity exists between the two genotypes.

In the Philippines, comparative reproductive performance of carabao (swamp) and F_1 carabao × river (Murrah and Nili-Ravi) was measured both in village and institutional herds (Momongan et al., these Proceedings). The F_1 hybrids reached puberty and produced their first calves about one year earlier than the straightbred carabao. Subsequent intercalving intervals of the F_1s were shorter (although not statistically significant) than those of their carabao contemporaries by about six months.

In Thailand, reproductive performance of the F_1 hybrids has been superior to that of the straightbred swamp type. Kamonpatana et al. (these Proceedings) have reported that F_1 (swamp × Murrah) females reached puberty at a younger age than purebred swamp females at two locations that differed in the availability of feed. In Vietnam, mean intercalving intervals of Vietnamese swamp buffalo were reported to be about 100 days longer than those of F_1 swamp × Murrah hybrids (Cuong and Trieu pers comm.). The Malaysian comparison (Mahyuddin et al., these Proceedings) is anomalous in that intercalving intervals were excessively long when compared to either previous estimates from the same farm or relative to estimates from other countries. In the present report, although the proportion of F_1 swamp × Murrah females resuming ovarian activity by 120 days post-partum was higher than that of the purebred Malaysian swamp, intercalving intervals were reported to be higher for the F_1 (799 + 384 days) than for the swamp (628 + 203 days).

In all of the above examples, data have originated from small numbers of animals. However, the superiority of the F_1 hybrid over the straightbred swamp type is almost completely consistent. This is a strong indication that the superiority of the F_1 hybrids is real and is not due to chance alone.

Reproductive studies within the project have concentrated on females. However, a study in Indonesia (Situmorang and Sitepu, these Proceedings) has examined some variables associated with male fertility. This is important not only because of the contribution of the male to reproductive rates of females, but also because karyotype differences between swamp and river types may be associated with problems at spermatogenesis. In the Indonesian study, there were no significant differences in the volumes of ejaculates obtained from swamp, Murrah or their F_1 hybrid, but semen from swamp bulls had the highest sperm concentration. However, the F_1 and the Murrah produced a greater number of ejaculates during weekly 15 minute tests. Time to first ejaculation on presentation of a teaser animal was also shorter for the Murrah and F_1 genotypes. Numbers of animals involved were low but the data do indicate that libido and semen quality of the F_1s are satisfactory.

Thus, the evidence presented by project scientists indicates that the reproductive capacity of the F_1 hybrid female is superior to that of the various swamp strains. The improvement achieved by crossbreeding has been consistent and it is doubtful if any other method currently available could match the magnitude of the increases or the simplicity with which they were achieved. Crossbreeding must therefore be given serious consideration whenever there is a need to increase reproductive rates of the swamp types.

Improvement of Draught Capacity

One of the prime functions of buffalo throughout the region is to provide draught power, including power for land preparation. This, although the F_1 (swamp × river) may have superior growth and reproductive rates, it is unlikely to be acceptable to most smallholder farmers unless it also has superior or at least equivalent draught capacity to the existing swamp types. Investigations of comparative draught capacity were therefore an integral part of the project.

Comparisons in Thailand (Bunyavejchewin et al. these Proceedings) examined differences between F_1 (swamp × Murrah) and Thai swamp buffalo in physical measurements associated with draught capacity. The F_1 generated more power than the swamp but ploughed at a faster speed. The net result was that the actual areas ploughed in 90 minutes were very similar (552 and 544 m^2 for the F_1 and swamp types, respectively). To achieve this result, the width of cut must have been about 13% greater for the plough drawn by the swamp animals and this may account for their slower speed.

Differences between genotypes in physiological measurements in response to work were small. Increases in rectal temperature, pulse rate and respiration rate in response to work for 90 minutes were similar for both genotypes which supports the conclusion reached from the comparisons of physical performance that both genotypes had similar net draught capacity. Comparisons in Indonesia (Situmorang and Sitepu, these Proceedings) of changes in rectal temperature, pulse and respiration rates in response to work are in complete agreement with the results from Thailand.

Thus, although the comparisons have been of limited scope, what evidence there is suggests that the draught ability of the F_1 (swamp × river) is at least equivalent to that of the straightbred swamp types.

Improvement of Milk Yield

It has long been recognised that the potential milk yield of the swamp types can be increased by crossing to a dairy-type river breed. It may therefore be expected that further comparisons of milk production of F_1 and swamp type could add little, if any, additional information to what is already known. However, additional information that is required is whether the higher milk yield of the F_1 has a detrimental effect on reproductive rates, particularly when they are fed poor quality diets. In the Philippines (Momongan et al., these Proceedings), milk yields of F_1 (carabao × Murrah) and straightbred carabao were compared when both genotypes were also rearing their calves. Comparative estimates of partial milk yields (overnight production only) were 653L and 195L for the F_1 and carabao respectively. Despite the higher yield of the F_1s their subsequent intercalving intervals were almost 200 days shorter than those of their carabao contemporaries. These results were obtained from animals fed adequate diets including concentrates but are further supportive evidence of the superiority of the F_1 as a multipurpose animal.

Additional Information Required

The comparisons conducted throughout the region as part of the project lead to the conclusion that considered overall, the performance of the F_1 (swamp × river) is superior to that of any of the swamp types to which the F_1 has been compared. No other method, genetic or environmental, can produce lasting improvements in overall productivity of the magnitude produced by crossbreeding in such a short time, Thus, wherever the need or the desire exists to increase overall productivity of the swamp types, crossbreeding must be seriously considered as the first step in the process. There are however several aspects associated with the production of crossbreds that need additional investigation before large-scale crossbreeding can be confidently recommended.

Male fertility

Crossing of the swamp ($2n = 48$) and river types ($2n = 50$) produces an F_1 that has 49 chromosomes. This unequal diploid number could be expected to lead to complications at meiosis with the possibility that reproductive rates of the F_1 could be reduced compared to those of the parental types. Comparisons by project scientists have produced strong indications that reproductive potentials of F_1 females are higher than those of the swamp types. However, the limited evidence from Indonesia (Situmorang and Sitepu, these Proceeedings) suggests that sperm concentration of the F_1s may be affected. This is not unexpected as previous studies using testicular tissue from F_1 bulls (see Barker et al., these Proceedings) have reported a high proportion of degenerating spermatocytes as well as other abnormalities. However, the practical significance of these conditions remains to be assessed both in AI and natural mating systems.

Since progeny of the F_1 must be either F_2 or backcross to either swamp or river types, their diploid numbers could be $2n = 48$, 49 or 50. Whether there are any differences in fertility of these different karyotypes has not been unequivocally demonstrated. The number of animals required to do so is large and regional cooperation will be required if a result is to be forthcoming within a reasonable time.

Identification of appropriate crosses

The Murrah and Nili-Ravi, which are quite closely related, were the only two river breeds used to generate the F_1s involved in the project. Within the swamp types, an unknown number of strains was used, unknown because there has been very limited differentiation of the swamp types from the different geographical regions. Mukherjee et al. (these Proceedings) have however begun investigations into genetic relationships between swamp types using biochemical polymorphisms and have reported significant genetic differentiation between ten populations sampled from Indonesia, Malaysia, Philippines and Thailand. While in all cases reported the F_1s produced from these different populations of swamp types have been shown to be more productive than the purebred swamp types, the possibility that other crosses would be more suited to particular regions or production systems remains to be investigated. F_1s of large mature size or high milk yield potential such as those obtained by crossing the swamp types to the Murrah or Nili-Ravi will not be the most appropriate animals in all circumstances. Other crosses utilising river breeds of lower milk yield potential or smaller mature size then the Murrah or Nili-Ravi, or different strains within the swamp types need to be investigated. Since the number of breeds and strains potentially available for crossbreeding is large, empirical testing of all possible combinations is neither logistically nor economically feasible. Initial testing must be confined to comparisons of genetically different groups that are known or thought to have the attributes desired in the crossbred. Methods for identification of these different groups have been outlined elsewhere (Barker et al., these Proceedings). Once the appropriate groups have been identified, effort could then be directed towards identifying the most desirable genotypes within those groups. This should be done as a matter of urgency before the implementation of any large-scale crossbreeding programs.

Development of appropriate breeding systems

Although the F_1 has been shown to have several productive advantages over the purebred swamp types it is only the first step towards the development of a breed that is more productive than the existing swamp types. Reproductive rates of the swamp types are too low to allow the continuous production of F_1s. Breeding policies must therefore be adopted that will maximise the productive advantages of the combination of swamp and river types. The options are to interbreed, backcross or cross to a third unrelated breed. It is likely that whichever system is adopted, productivity will decline relative to that of the F_1. However, in some environments or production systems the decline may be of minor practical significance. At the current state of knowledge of buffalo genetics, the magnitude of any decline in productivity from the F_1 cannot be predicted. Even so, unless the comparative productivities of crossbreds with $2n = 48$, 49 or 50 were shown to be markedly different, it is doubtful if this knowledge would have any significant impact on short-term breeding policies. The production from the F_1 of some $2n = 49$ animals is unavoidable regardless of which breeding system is adopted. Low reproductive rates combined with the need to maintain or increase numbers dictate low culling rates and any decision to cull an animal is likely to be made for reasons other than its karyotype even if the karyotype was known. However, if it was shown that crossbreds with $2n = 49$ had a productive disadvantage, long-term breeding policy should aim at their elimination. This is likely to be an expensive and time-consuming exercise and reinforces the urgency to determine comparative productivities of $2n = 48$, 49 and 50 karyotypes before any large-scale crossbreeding schemes are implemented.

The question of karyotype aside, the main aim of any initial breeding policy should be to establish the relative proportions of swamp and river types required in the commercial animal. This is likely to vary depending on the environment and the production system used and will have to be determined for each particular set of circumstances. Since the opportunity for using within-breed selection to alter gene frequencies in village populations of draught buffalo is low, the required combination of breeds needs to be set in the first stages of crossbreeding. After that, interbreeding is likely to be the only feasible system for maintaining approximate combinations of the required genes.

Comparative draught capacity

The prime function of non-dairy buffalo is to produce draught power and additional evidence on the comparative draught capacity of crossbreds and swamp types would increase confidence in any decision to launch wide-scale crossbreeding programs. In this context, studies conducted under the Draught Animal Power project are of major significance.

Efficient production of F_1s

It is likely that the number of exotic bulls available for crossbreeding purposes will be very limited for at least several buffalo generations and AI will continue to be used as the main method for producing F_1s. However, project scientists have consistently reported low success rates where AI has been used in village herds. If crossbreeding is to make a significant impact at the national level, efficient, simple low-cost methods for improving the success of AI have to be developed. Areas for research might include methods for prolonging the life of sperm in the female reproductive tract or more efficient synchronisation and detection of oestrus.

Comparative resistance to environmental stresses

Most buffalo spend their entire life in relatively stressful environments and to function satisfactorily they must have a high level of resistance to the stresses of these environments. Differences in resistance are expressed through differences in mortality, particularly in calves, differences in growth or reproductive rates, or as differences in physiological responsiveness, particularly to work. Insufficient data on comparative mortalities of F_1s and pure swamp types have been generated within the project to decide whether biologically significant differences do exist. However, the limited evidence that is available suggests that there are no major differences in mortalities between the two genotypes. The comparative advantage of the F_1s over the swamp types for growth and reproduction and their similar physiological response to work also suggest that if there are any differences in resistance to environmental stresses between the two genotypes they are small. However, in all instances, it has been F_1 animals that have been compared to the swamp types. These F_1s are a unique generation with a unique combination of parental genes that is not found in any other generation. Because of this, resistance of the F_1 is likely to be close to that of the more resistant purebred parent. This may give a false impression of the level of resistance to be expected in subsequent generations of crosses. As segregation of the genes that control resistance occurs in the F_2 or if the F_1 is backcrossed to the less resistant parental breed, the mean level of resistance will decline. Lack of resistance could then become an important determinant of the comparative productivity of subsequent generations of crosses.

To be certain of the value of any particular cross to provide a sustained lift in productivity, the characteristics of the F_2 or backcross generations need to be known. Insufficient data are available from within the project from which to draw firm conclusions. However, in Thailand (Bunyavejchewin et al., these Proceedings) the lower post-weaning gains of both purebred and backcross Murrah compared to pure swamp animals and the F_1 hybrid suggest that the Murrah has lower resistance to environmental stresses than the swamp type.

These results suggest that in those regions where buffalo are used mainly for purposes other than milk production, upgrading of the swamp type to Murrah will reduce productivity. Whether this reduction is associated with lower resistance to environmental stress of the Murrah (though not necessarily other river breeds) remains to be determined. Regardless of the reason, the limited data available do suggest that it will be crossbreds rather than purebreds that will be the most productive animals.

It would be very naive indeed to assume that all of the answers for solving the problems associated with low productivity of swamp buffalo are already known. The project has simply laid the foundations for finding solutions. Continuation and extension of these studies will be required if crossbreeding is to make an effective contribution to improvement of swamp buffalo populations at the national level. This will not happen without continued support for and interest in the buffalo project.

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Participants

Dr Tengku Azmi
Faculty of Veterinary Medicine and Animal Science,
Universiti Pertanian Malaysia,
43400 Serdang, Selangor
Malaysia

Dr Zainal Aznam Jelan
Department of Animal Sciences,
Universiti Pertanian Malaysia,
43400 Serdang, Selangor,
Malaysia

Dr C.R. Balakrishnan
National Dairy Research Institute,
Karnal-132001
(Haryana),
India

Prof. J.S.F. Barker
Department of Animal Science,
University of New England,
Armidale, NSW 2351.
Australia

Mrs Pakapun Bunyavejchewin
Buffalo & Beef Prod. Res. and Development Centre,
Kasetsart University,
Bangkhen, Bangkok 10900,
Thailand

Prof. R.H. Crozier
Department of Genetics and Human Variation,
La Trobe University,
Bundoora, Vic. 3083.
Australia

Mr Le Xuan Cuong
Agricultural Insitute of Vietnam,
Ministry of Agriculture (Cattle and Buffalo Research Department,
121 Nguyen Binh Khiem Street,
No. 1 District,
Ho Chi Minh City,
Vietnam

Dr G. Davis
CSIRO Division of Tropical Animal Production,
Tropical Cattle Research Centre,
Box 5545 Mail Centre,
Rockhampton, Qld. 4702.
Australia

Fongpaik Quai
59 Jalan 11/4,
46200 Petaling Jaya,
Kuala Lumpur,
Malaysia

Dr J.E. Frisch
CSIRO Division of Tropical Animal Production,
Tropical Cattle Research Centre,
Box 5545 Mail Centre,
Rockhampton, Qld. 4702.
Australia

Dr Y.Y. Gan
Department of Biotechnology,
Universiti Pertanian Malaysia,
43400 UPM, Serdang, Selangor
Malaysia

Ms Connie Halbeiten
Research Fellow,
Institute for Advanced Studies,
University of Malaya,
59100 Kuala Lumpur,
Malaysia

Dr Mohd Hilmi Abdullah
Faculty of Veterinary Medicine and Animal Sciences,
Universiti Pertanian Malaysia,
43400 Serdang, Selangor
Malaysia

Dr D. Hoffmann
Research Program Co-ordinator,
Animal Sciences,
ACIAR,
GPO Box 1571,
Canberra, ACT 2601,
Australia

Prof. Maneewan Kamonpatana
Faculty of Veterinary Science,
Chulalongkorn University,
Henri Dunant Street,
Bangkok 10330,
Thailand

Mr P. Lynch
Proceedings Editor,
ACIAR,
GPO Box 1571,
Canberra, ACT 2601,
Australia

Mrs B. Marler
Administrative Assistant,
CSIRO Division of Tropical Animal Production,
Tropical Cattle Research Centre,
Box 5545 Mail Centre,
Rockhampton, Qld 4702.
Australia

Prof. Mohamed Mahyuddin Dahan
Fakulti Sains & Teknologi Makanan,
Universiti Pertanian Malaysia,
43400 UPM,
Serdang, Selangor,
Malaysia

Dr A.R. Mohamed
Department of Animal Science,
Faculty of Agriculture,
University of Ruhuna,
Kamburupitiya,
Sri Lanka

Prof. Vincente G. Momongan
Institute of Animal Science,
University of the Philippines at Los Baños,
College, Laguna 4031,
Philippines

Prof. T.K. Mukherjee
Institute of Advanced Studies,
University of Malaya,
59100 Kuala Lumpur,
Malaysia

Dr R.K. Munro
Bureau of Rural Resources,
Department of Primary Industries and Energy,
GPO Box 858,
Canberra, ACT 2601.
Australia

Dr J.M. Panadam
Institute of Advanced Studies,
University of Malaya,
59100 Kuala Lumpur,
Malaysia

Dr Benedioto A. Parker
Institute of Animal Science,
University of the Philippines at Los Baños,
College, Laguna 4031,
Philippines

Dr B.M.A.O. Perera
Animal Production and
Health Section,
Joint FAO/IAEA Division,
PO Box 100,
A-1400 Vienna,
Austria

Mrs J. Sambhi
ACIAR Liaison Officer,
C/o Australian High Commission,
Kuala Lumpur,
Malaysia

Mr Selvaraj O.S.
Institute of Advanced Studies,
University of Malaya,
59100 Kuala Lumpur,
Malaysia

Dr F.H. Shah
Genetics Department,
Universiti Kebangsaan Malaysia,
Bangi, Selangor,
Malaysia

Dr P. Situmorang
Balai Penelitian Ternak (BPT),
PO Box 123,
Bogor 16001, West Java,
Indonesia

Dr P. Sitepu
Balai Penelitian Ternak (BPT),
PO Box 123,
Bogor 16001, West Java,
Indonesia

Mr Sreetharan
Institute of Advanced Studies,
University of Malaya,
59100 Kuala Lumpur,
Malaysia

Dr S.G. Tan
Department of Biology,
Universiti Pertanian Malaysia,
43400 UPM, Serdang, Selangor
Malaysia

Em. Prof. N.M. Tulloh
1 Wilgra Avenue,
Ashburton, Vic. 3147,
Australia

Dr J.E. Vercoe
CSIRO Division of Tropical
Animal Production,
Tropical Cattle Research Centre,
Box 5545 Mail Centre,
Rockhampton, Qld 4702.
Australia

Ms Yushayati Yusof
Institute of Advanced Studies,
University of Malaya,
59100 Kuala Lumpur,
Malaysia

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