Yak breeding programmes in China

Wu Ning

Chengdu Institute of Biology, Chinese Academy of Science,
610041 Chengdu, China

Introduction

The yak (*Bos grunniens*) is one of the most important species of livestock found in the Himalayas and on the Tibetan Plateau. Totalling about 15 million animals, yaks and yak-hybrid crosses provide multiple products for the subsistence and marketing of local communities (Miller *et al*, 1997). In fact, the yak is a unique animal, native to Central Asia and well adapted to the cold, high altitude environment where it is found. As such it is very significant to conserve and manage yak genetic diversity for sustainable pastoral development over a large geographic area.

Western Sichuan, the case-study area, is located in the most eastern region of the Tibetan Plateau and plays the most important role in the connection between the Plateau and the lowland of China both economically and ecologically. This Region has a long history of yak breeding with pronounced local economic characteristics. Following Qinghai and TAR (Tibetan Autonomous Region), Sichuan Province ranks the third most important province / region in China for yak breeding, where the number of yak amounts to 26 percent of the national total (Wu, 1997a).

Yak breeding and cross-breeding in Sichuan

Although the yak is indispensable across the Tibetan Plateau and neighbouring regions, this animal is a unique bovine with relatively low productivity. As a result, herdsmen have been adopting various means to improve yak productivity for years. Most significantly, herdsmen have developed methods of cross-breeding to produce yak hybrids. In the past few decades, several breeds of cattle with a large body and high productivity have been introduced into China's yak population.

Main Yak breeds

The different breeds of yak existing in high altitude areas have for a long time been selected by local herders. Owing to its multipurpose, yak not only has a very high value in terms of economics, but also in genetic resources. To date, two breeds (types) of yaks have been identified in

Sichuan, for example, Valley type (*Jiulong* Yak) and Plateau type (*Maiwa* Yak) (Cai, 1989; 1992), both of which are the main breeds involved in yak genetic improvement schemes.

Production system concerned

The sparseness and limitation of natural pastures and their geographic location contribute to the formation of mobile yak-keeping characters in the Tibetan Plateau. In general, with the seasonal alternation, the yak herds repeatedly often have to cover a large distance in search of foodstuff and water, which leads to the migration on seasonal pastures. Traditionally, yaks are reared in range systems with very low input level and are never housed even during the worst climatic conditions. These animals live entirely on natural pasture but occasionally the lactating animals are given barley flour with common salt, but are never accustomed to any concentrate ration. They graze in community. If enough herdsmen are available, the dairy animals are separated from the rest. Generally speaking, it appears (in the absence of actual intake of nutrients), that the animal has the special adaptability to live in areas of scarce feeding conditions without having a detrimental effect on their health.

Approximate number of animals concerned

In Sichuan, the yak population has shown an increasing trend in the last four decades, which has recorded an increase from 1.67 million to 3.97 million from 1950 to 1995, for example, an increase of 137.7 percent (Ao *et al*, 1988; SSB, 1996). The largest population of yak in Sichuan is distributed in the north-western counties, such as *Serqu*, *Dege*, *Sertar, Zoige*, *Hongyuan* and *Aba*, where the population in every county is more than 200 000 heads. Transgressing the borders southwards, there are seven counties where the population of yak is above 100 000. The percentage of yak hybrids in yak population increases with the rise of altitude and the role of livestock husbandry in agricultural production. More hybrids are found in areas with a greater relative difference of elevation (mountain regions) or agro-pastoral areas.

In *Hongyuan*, the centre where the *Maiwa* breed is distributed, there were 350 000 head of yaks (including hybrids) in 1995 (SSB, 1996), among which there were about 300 000 head belonging to the *Maiwa* breed. It is estimated that there was a total of 700 000 head of *Maiwa* Yak distributed in the north-western plateau of Sichuan. It is also the yak breed with the biggest population in China. At present, there are about 100 000 head of yaks in Hongyuan involved in the straight-breeding programme of Maiwa breed and 1 200-1 500 head of female yaks concerned with the cross-bred programme. The approximate number of another important breed, *Jiulong* Yak, is about 50 000 head, among which there are about 20 000 head of breedable female yak. There are only 600 head of yak bulls taken to other places for breeding or cross-breeding. Others are totally reproduced with the straight-breeding method.

Breeding goals and traits included

Generally speaking, from time immemorial breeding and cross-breeding of yaks have been practised with two main goals:

1) To have a type of improved or cross-bred animal which suits the harsh climate. With the expansion of yak from the original area, pure-breeding and cross-breeding began to be practised. For example, in order to suit the environments in mountainous regions, such as apparently vertical difference (steep gradients), diverse foodstuff (different herbaceous plants and feedings in different seasons), transhumance systems and inaccessibility, the '*Jiulong* breed' was selected around the Jiulong County which is called 'valley type'. In the north-western Sichuan the plateau has many morasses or semi-boggy areas, hill-shaped highlands with gentle slopes and broad valleys present in an open kind of topography. A little higher precipitation and humidity make the alpine and subalpine meadows predominated by dense grasses and sedges. Due to the open topography, the seasonal migration of nomads is more horizontal and yak tends to migrate freely. Bulls (even wild yak bulls at the beginning of this century) move from one area to another and mate with individual cows or even whole herds in neighbouring areas. In geo-ecological background and nomadic conditions, the '*Maiwa* breed' (plateau type) was selected.

2) To enhance the productivity of yak to meet the subsistent or marketing requirements. Owing to the difference of life-style, the purposes of breeding or cross-breeding are varied in different groups of pastoralists. For example, the yaks of the *Maiwa* breed are of relatively good milking capacity with high butterfat content of milk. These yaks are clearly multipurpose, being mainly used for milk and meat. On the contrary, the yaks of the *Jiulong* breed have good productivity in meat and hair and have been selected with meat, hair and draught in mind (Table 1). Presently, marketing requirements always dominate the objectives of breeding or cross-breeding. In the last few decades, owing to its big body size, high productivity and ideal adaptability to the mountain environment, the *Jiulong* Yak has been introduced to many yak-raising regions, such as Yunnan, TAR, Gansu and Qinghai, for straight-breeding or cross-breeding.

Approaches adopted for breed selections

In the regions where yak products are in great demand and sought after in the market place, it seems that herdsmen have acquired both the knowledge and skill to improve production traits. In Sichuan the indigenous knowledge of traditional yak breeding can be found popularly in pastoral societies, but most of them have not been described systematically. The system of selection in *Jiulong* is an exception, which has been sifted out and discussed in some literature (Cai, 1989; 1992; Cai and Wiener, 1995; Wu, 1998). Here only the traditional selection procedure used by herdsmen in the *Jiulong* area is reviewed briefly.

Table 1. Comparison of Typical Traits between Jiulong Yak and Maiwa Yak.

Items	Jiulong yak	Maiwa yak
Centre of distribution	Jiulong, southern Kangding (including Muli, Yanyuan, Mianning and Shimian)	Hongyuan, southern Zoige (including Aba, Songpan, Nanping and Zamtang)
No. of heads	50 000	700 000
History of selection	130 years	about 100 years
Colour of hair	black (most), black-white (a few)	black (most), as well as black-white, grey, brown and white
Horn	occurring in all yak	occurring in most yak
Body weight (kg)	400 - 700 (M); 200 - 400 (F)*	300 - 500 (M); 150 - 350 (F)
Height (cm)	130 - 140 (M); 110 - 120 (F)	120 - 130 (M); 100 - 110 (F)
Selecting purpose	meat, milk and hair	milk and meat
Dressing percentage (%)	50 – 60	50 - 60
Dressed carcass (%)	40 – 50	40 - 50
Milk yield during lactation (kg)	200 – 500	200 - 400
Butter-fat content (%)	5 – 8	6 -7
Hair yield (kg)	13 - 20 (M); 1 - 3 (F)	2 - 12 (M); 1 - 3 (F)
Packing capacity (kg)	60 - 75 **	70 - 100
Travelling distance with burden (km)	20 - 25	30

Source: Cai, 1990.
Note: * M = male yak; F = female yak.
** This number was measured with castrated yak (bullock).

1) Selection of male yak (bull)
In the *Jiulong* area, the choice of male yak is stricter than that of the female. The guiding principle for the herdsmen is to check the ancestors (parents) first and the bull second. The criteria of selection are summarised in table 2.

The selection of male yaks (bulls) in the *Jiulong* area is carried out in three stages. The first is pre-selection at the age of one-year olds. There is a second selection from among the first group at the age of two years and a final selection at the age of three or four years. Culled bulls are castrated and used for meat or draught purpose.

2) Selection of female yak (cow)
The criteria for female yak are simpler and mainly concentrate on reproduction. To summarise, the indigenous knowledge of herdsmen, can be expressed as “three elimination”, namely:

- eliminating the female yaks when they reach the age that should give the first-birth (four to five years old), but no calves are born;
- eliminating the barren or non-pregnant female yaks through three to four years;
- eliminating the female yaks that have not enough maternal instinct to look after the growth of their babies.

Table 2. Traditional criteria for the selection of Jiulong yak.

Ancestors (parents)		Bulls (themselves)
Female (mother)	Male (father)	
• high milk yield; • good conformation • (big body); • tame and gentle; • given birth twice to • calves	• rich and thick hair; • numerous descendants	• rough bases of horns and long distances • between them; • horns stretching outwards and widely; • broad forehead, muzzle and mouth; • thin and long lips; • thick neck, high withers and wide brisket; • wide and flat back, loin and rump; • straight forelimbs and curved hind-legs; • hairy tail and shrunken scrotum; • black coat or black with some white specks • on the forehead and at the extremities of the • body (e.g. legs, tail).

Source: Cai, 1989; Cai and Wiener, 1995.

Selection criteria

The defined purposes of selection in China aim at accelerating the speed of individual maturing and increasing growth rate. Strictly speaking, there was no systematic selection scheme carried out for yak to date (Cai, 1992). In order to promote the identification of yak breed, the selection criteria were drafted out at the end of the 1970s and perfected in the 1980s. In Sichuan the selection of *Jiulong* yak is concentrated on meat and hair (or downhair) and in *Maiwa* yak milk and beef (Table 3).

Table 3. Selection criteria for Jiulong yak and Maiwa yak in Sichuan.

Items		Jiulong yak (Valley type)		Maiwa yak (Plateau type)
	Purpose	Meat and milk	Meat and hair	Meat and milk
Body size (cm)	Height (cm)	125 – 145	120 - 135	120 - 140
	Length (cm)	140 – 170	140 - 170	
	Heart girth (cm)	190 – 225	200 - 230	
	New birth	18 – 20	18 - 20	
Body weight (kg)	180 days (stop suckling)	100 – 120	100 - 120	115
	1.5 years old	200 – 250	210 -260	135 - 155
	Adult	350 – 600	370 - 630	350 - 600
Productive properties	Dressing percentage	above 58 %	above 60 %	60 %
	Dressed carcass (%)			50
	Milk yield (kg)	above 1 000	above 1 000	306*
	Butter-fat content (%)	6.2	6.0	above 6.5
	Hair yield (kg)	1.5 - 2.0	4 - 12	2 - 3

Source: Cai, 1992.
Note: milking once a day for 153 days.

Whether a pastoral community opts for pure breeding and/or cross-breeding depends not only on the actual environmental circumstances, but also on their cultural traditions. It is interesting that the distribution of the valley-type yak and the Plateau-type yak mirrors the traditional distribution of the Kham Tibetan and the Amdo Tibetan (Wu, 1998). The central area of Jiulong yak distribution has for many centuries been the homeland of the Kham Tibetan people. Traditionally, they chose pure breeding as the main method for selection and even today cross-breeding is rarely practised. This has to do with the topography of the area: high mountains with deeply incised valleys restrict the exchange of yaks. Only in the adjacent area where the altitude is lower and cultivated fields spread, some hybrids between yak and cattle ("*Pian Niu*' in Chinese), making up ten percent of total heads of yak herd, can be found which are cross-bred with the purpose of draught.

The region of the plateau-type yak distribution is inhabited by Amdo Tibetan who are thought to be the descendants of the ancient Qiang people of northern China. Owing to its geographical accessibility, cross-border exchange or trading of yaks existed not only in the Amdo area itself but also between different ethnic groups. Moreover, bulls for breeding could easily be introduced from the adjacent areas suitable for crop cultivation.

The historical migration of nomadic tribes, including the Qiang, Tibetan and Mongolians, also introduced new yak breeds and promoted genetic exchanges (Wu, 1999). As a result, it is cross-breeding which is most often practised in this Region and hybrids are very common. In *Zoige* County, for example, the hybrids represent 20-30 percent of total head of yaks. Even so, in the original home of the *Maiwa* breed, the number of hybrids is still kept below six percent and straight-breeding is the principle mean for yak improvement.

Brief history of cross-breeding plan

The traditional selection methods for breeding appear to have produced, over a period of many centuries, an improved breed of yak which is highly regarded (Cai and Wiener, 1995). However, the development of pastoralism would need to encourage the herdsmen to pay more attention to the productive characteristics of yaks. In Sichuan the strengthening of yak productive potential usually entails genetic up-grading of indigenous breeds with high yielding exotic stock.

In the yak-raising area, the cross-breeding between yak and cattle (*Bos taurus*) can be dated back historically to at least 3 000 years ago, when Qiang people adopted these methods to reproduce '*Pian Niu*' (including '*Dzo*' and '*Dzomo*'). With the development of cultivation in the adjacent mountainous regions, the cross-breeding was increased and a wealth of experience accumulated. Through numerous tests and practices, the cross-breeding between cattle bull and yak cow is identified as the ideal method by herdsmen. Meanwhile, it is also found that male sterility exists within the hybrids (F_1), but the female hybrids (*Dzomo*) are able to reproduce. In Aba Prefecture cross-breeding is only carried out for two generations. The F_1 animals are called '*Pian Niu*' and F_2 '*Za Niu*'. The F_2 can be further divided into two kinds: '*Mao Za*', the progeny between male yak and *Dzomo*; '*Huang Za*', the progeny between male cattle and *Dzomo.*

In the last three decades many improvement schemes have been used to improve breeds of cattle of dairy, beef and/or dual-purpose type. The work has been facilitated with the introduction of artificial insemination (AI) and the use of frozen semen. The name given to the first cross between yak and exotic breed is 'Improved *Pian Niu*'. Viewing the improvement activities in yak cross-breeding, the results that have been obtained in Sichuan and the opportunities created for improvement are described as follows:

1) Eliminating backcrosses '*Za Niu*'. This is a traditional method to maintain the development of stock. Only the F_1 animals ('*Pian Niu*') are used for production (for example, not for breeding), and all of their progenies ('*Za Niu*') are eliminated. This practice aims at harvesting all milk from the F_1 cross-breed (*Dzomo* in Tibetan), strengthening the availability of hybrid vigour and preventing the degradation of hybrid

quality. The problem of this practice is that it is not appropriate for the poor herdsmen who only own a small stock of animals and thus refuse to cull out any backcrosses.

2) Culling out '*Huang Za*' (progenies of backcrosses with cattle) and developing '*Mao Za*' (progenies of backcrosses with yaks). In order to restore and develop the yak husbandry, in the 1950s and 1960s the Government encouraged pastoralists to adopt this method instead of killing all of the backcrosses. This plan was based on the fact that the progenies of backcrosses with yaks can keep the productivity of yak better than that of the progenies of backcrosses with cattle and the hybrid vigour degrades more slowly. This improvement activity stimulated the development of yak husbandry in Sichuan and the hybridisation and utilisation of hybrid vigour made further progress. Until the middle of the 1970s the number of yaks (including cross-bred progenies) in Sichuan increased from 1.34 in 1950 to 2.7 million in 1974. This strategy was accepted and widely adopted in the north-western plateau where there is a tradition for hybridisation. It should be mentioned that this method is also combined with the selection and culling of F_2 hybrids in order to control their proportion in stock. Only the strong progenies of backcrosses with yaks are kept for draught and also culled out when they are old. The yak bulls for cross-breeding are also used for straight-breeding in yak stock. The progenies of backcrosses with yaks are mainly used for draught or trading with farmers, the number is very limited in such a high altitude area. Pure breeding is still the main method for herders.

3) Introducing improved cattle breeds (bulls) and cross-breeding with yak. In order to further utilise the hybrid vigour, it is necessary to remove the defects of local cattle and increase the economic return of hybridisation. In the 1960s eight breeds of cattle, such as Simmental, Holstein Friesian, Charolais, Hereford and Shorthorn, were introduced. They were raised in some pastoral counties, such as Zoige, Aba, Hongyuan and Sertar, and further crossed with yak. In this way some F_1 hybrids ('Improved Cross-breeds', '*Pian Niu*" in Chinese) were obtained, whose properties were apparently better than those of local cross-breeds ('*Pian Niu*' in Chinese) (Table 4). Even so, however, the actual socio-economic benefits were not as high as it was hoped because the introduced cattle breeds could not adapt totally to the high-altitude conditions and nomadic grazing systems and lost their mating ability gradually. In Sichuan there were no more than 1 000 cross-bred progenies of the introduced improved sire (bulls) after 20 years and until the 1970s the 'Improved Cross-breeds' obtained this way were less than 500 head. Finally, the improved sires for cross-breeding purpose were almost extinct until the end of the 1980s.

Table 4. Comparison of the properties among Yak, 'Local Cross-breed' and 'Improved Cross-breed'.

Items	Yak	Local cross-breed Yak (f) × cattle (m)	Improved cross-breed Yak (f) × HF (m)
Height at withers (cm)	109.7 (f); 123.9 (s)	118.3 (f); 128.7 (s)	121.8 (f); 144.0 (s)
Body length (cm)	138.1 (f); 161.5 (s)	148.0 (f); 173.0 (s)	152.3 (f); 178.3 (s)
Heart girth (cm)	160.3 (f); 198.0 (s)	167.9 (f); 197.3 (s)	182.7 (f); 215.6 (s)
Cannon bone circumference (cm)	16.9 (f); 20.6 (s)	17.0 (f); 20.3 (s)	18.5 (f); 21.3 (s)
Adult weight (kg)	249.0 (f); 443.0 (s)	292.0 (f); 476.6 (s)	356.5 (f); 580.0 (s)
Weight of new-born (kg)	18.7 (7.5 - 27.5)	17.5	22.5 (14.5 - 25.5)
Dressing percentage (%)	53.7	52.7	52.0
Carcass percentage (%)	42.0	40.0	41.0
Daily milk yield during lactation (kg)	2.0	3.0	8.0
Butter-fat content (%)	6.3	6.0	5.3 - 5.5

Source: 1) CAI, 1989; 2) Annual report of *Longri*, Hongyuan County.
Note: f = female; m = male; s = steer (castrated male).
cattle = local cattle; HF = Holstein Friesian or (75 percent HF + 25 percent local cattle).

4) First cross-bred generation ("*Pian Niu*") for dairy purpose and backcross ("*Za Niu*") for meat purpose. From the beginning of the 1980s this improvement scheme has been implemented in western Sichuan. Its purpose was to raise the yield of milk with the cross-breeding between female yak and improved bulls of dairy types (e.g. Holstein Friesians), and the yield of meat with the cross-breeding between cross-bred F_1 and improved bulls of meat types. In this way all backcrosses were used for meat purpose which accelerated the turnover of bovine population. Owing to the increase in milk yield and economic return, this plan has been disseminated to a certain extent in pastoral areas. Until 1985 the number of 'Improved Cross-breed' for dairy purpose in this plan was about 3 000 head (Cai, 1989). However, it should be mentioned that this work was facilitated by the introduction of AI. The use of AI is and has been inevitably restricted to more accessible areas. Moreover, the expense to herdsmen, of using AI or having bulls of the improved breeds of cattle (as well as their poor survival) means that, except in a few localities, this plan cannot be carried out effectively without relatively high input from governments or development agencies. So far no herdsmen in case study areas have engaged in this practice with their own investment.

On-going cross-breeding programme

With the privatisation of rangeland in the 1990s, an integrated development programme was initiated. Combined with the infrastructural construction, such as the construction of settlements for nomads, sheds for animals and

cultivation of hay meadows, the improvement of yak and increasing the economic benefits of animal husbandry have also been included in the framework. After considering the various methods adopted during the last few decades, a more practicable method was suggested and implemented. As the improvement of cattle has been largely carried out in adjacent mountainous farming areas for some years, the F_1 male cattle that are always culled and used only for beef may be used in pastoral areas for yak improvement. This kind of bull is more adaptable to high altitude and harsh environment than its present father, on one hand and on the other hand, has higher potentiality in dairy production than local cattle did. Furthermore, in this way, bulls for cross-breeding are easier to obtain, the expense is acceptable for pastoral households, economic return is higher and the offspring are more adaptable. The detailed process is shown in figure 1.

Dissemination and breeding structure

The geographic location of pastoral western Sichuan naturally provides the accessibility to the exchange of animals and their products among pastoralists in plateau and farmers in mountainous regions. Traditionally, the original cross-breeding activities were carried out by yak herders along the eastern fringe of the Tibetan Plateau, for example, the agro-pastoral areas. The introduction of cattle for cross-breeding with yaks, therefore, is in line with the traditional practice of yak herders. However, the difference

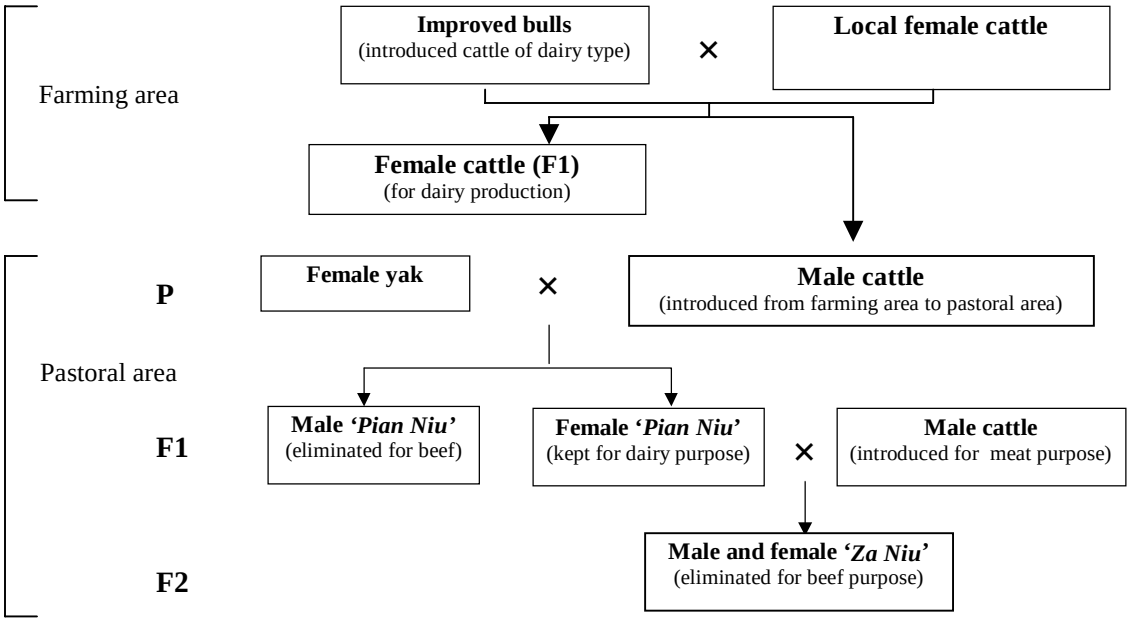

Figure 1. On-going cross-breeding plan.

between the on-going programme with traditional activities is that the introduced bull is an improvement on the pure local cattle, which may have greater potential for dairy production. On the other hand, it has stronger adaptability than the improved bull (such as Holstein Friesians) used in the last improvement schemes. Although the improvement programmes in both farming and pastoral areas are promoted by Government and development agencies, the local herders willingly accept this method due to its traditional and low expense. At the beginning of the 1990s a few bulls were introduced by institutions responsible for the technical support in the integrated development programme. With the demonstration in a few nomadic households, more and more nomads recognise the advantages of this practice. The introduction of bulls from farming areas is operated occasionally by individual herders themselves, step by step with the support of technicians and Government. Generally, an introduced bull is shared by a number of households having a joint investment.

Although the cross-breeds can provide more dairy products for the nomadic family, they still need more supplementary feeding during winter and spring. If herders want to keep the high productivity of hybrids, more attention should be paid to management. In general, the introduced cattle bull is raised separately in an enclosed pasture, which is close to a winter settlement of pastoralists and the hybrids are always separated from the yak herd. As the labour input is relatively high and the duration of the programme is short, the number of cross-breeds obtained in this way is only about 1 200 head in Hongyuan, the demonstration county and only make up 0.34 percent of the total yak stock.

Participation and technical support

Since the improvement of yak has been tested and carried out in western Sichuan for a few decades, abundant experiences both positive and negative have been accumulated. In the 1990s when the integrated development programme was implemented in pastoral areas, the Government was still the organizer, but experts from institutes, such as the Sichuan Rangeland Institute and Southwest Nationality College, gave technical support. At the beginning of the programme, the investment in the introduction of cattle bulls (male progenies of pure-bred foreign bulls with local cattle cow) from neighbouring mountain areas, was afforded by the programme, for example, from the Government. The experts are responsible for the demonstration in ten to twelve selected households in Hongyuan County. A series of training courses were conducted by technicians and herders from demonstrated families also worked as interpreters. Owing to its operational techniques, low investment and high economic benefits from milk selling, about 40-45 households were involved in this improvement scheme.

Main reasons for introducing the scheme and significant activities

Together with the traditional breeding goals mentioned above, looking for a breed with stronger adaptability to harsh environment and the marketing value are two major driving-forces for yak improvement. The purpose of cross-breeding initiated by the Government is, therefore, to combine some of the good qualities of the breeds being crossed and to anticipate the possibility that the performance of the crosses will exceed the average of the two parental types (in terms of heterosis or hybrid vigour).

Recent changes in production orientation from subsistence to more marketing in China drive the implementation of yak improvement. In Hongyuan County, one of the demonstrating counties for the integrated development programme, for example, in order to sell the surplus milk to the milk-powder factory located in the town, herdsmen need to have a breed with higher milk production. Traditionally, selling of dairy products is one of the most important sources for the income of local households including revenue for the Government, which has been reflected from the selection criteria of *Maiwa* Yak. Furthermore, one of the aims of the on-going integrated development programme is to promote the transformation of pastoralism from subsistence to marketing. With this original intention, the Government also needed to push forward the implementation of the yak improvement scheme in pastoral areas. Officials think that the situation of rangeland degradation could be changed through the increase of animal productivity, turnover rate of animal stock as well as the cultivation of artificial pastures. The development of hay meadows by every household provides the possibility to raise 'improved' yak hybrids individually. The limits of foodstuff in winter, labour in most households and seasonal migration of herds, however, still hinder the expansion of yak hybrids on a larger scale. Although the privatisation of the rangeland among nomadic households reduces the mobility of yak keepers, most households still adopt the traditional way for animal husbandry. The sparse and higher summer pasture cannot always provide enough foodstuffs to keep the high yield of lactating hybrids. The remote summer pasture is also far from the main road where the milk-powder factory collects milk from nomads. After the 'settling down' of nomads through the integrated development programme, the old people and children in the family always stay in their winter settlement all year round. They become the main labour responsible for hybrid raising with the help of women in the family during the lactation season.

Major challenging issues and future directions

Ways of improving yak productivity by selection, as contrasted to cross-breeding, might be thought to be of great importance to the people who depend on yak for their livelihood. Yak is an integral component of the socio-economic system of people in these remote areas. However, in the past and even in present times, several factors work against systematic breeding programmes.

Major challenging issues within Yak breeding and cross-breeding

At first, it was believed that yaks are still widely regarded, especially among Tibetan people, as a symbol of wealth, which is the main constraint for the genetic selection of yak (Cai and Wiener, 1995). Since the transformation from subsistence to marketing orientation is a slow process, the improvement of yak cannot be accepted widely in a short time, especially in remote areas. Furthermore, it is also impossible for the remote pastoral area to implement the cross-breeding programme where there is no effective market system for animal products and not enough foodstuff for animals.

Secondly, it was emphasised that an important reason why genetic selection by herdsmen or extension officers acting on their behalf, is hindered, is the absence of the necessary performance and pedigree records, although herdsmen will often claim to know the parents of the animal, especially bulls. In fact, the indigenous knowledge about breeding and cross-breeding has existed in pastoral societies for a long time and has functioned in a rational way. The only reason why it cannot be systematised and understood is that there is not enough technical capacity in these societies.

Thirdly, survival of yaks in a harsh, even hostile environment is of paramount importance, perhaps of higher priority than any single performance trait. In terms of selection for survival in these conditions, natural selection is almost certainly more effective than any current procedure devised by man (Cai and Wiener, 1995; Wu, 1997a). In addition, owing to the lack of sufficient knowledge on practical conditions including ecological, socio-economic and cultural, the activities or outcome of most projects for yak improvement which were coordinated by governments in the last three decades, cannot be sustainable.

Future directions

The improvement of yak in the high-frigid plateau is or will be inevitable and necessary, but it should also not be forgotten that yaks are reared in range systems and never housed even during the worst climatic conditions. The sustainable viewpoints cannot be omitted in any projects related to the development of the yak industry and all of the 'modern' techniques for breeding and cross-breeding cannot be introduced simply or directly without any practical evaluation (Wu, 1997b). Although the on-going cross-breeding scheme is relatively more successful than that carried out before (including the schemes mentioned in Section "Brief history of cross-breeding plan" such as eliminating backcrosses, culling out progenies of backcrosses with cattle and developing progenies of backcrosses with yaks, introducing foreign bulls to cross-breed with yak, and first cross-bred generation for dairy and backcross for meat), some aspects should also be improved if a sustainable approach is to be established, namely to:

- establish a small herd of pure yaks to carry out observations on performances in different systems of management. In this way the

steady genetic features of different breeds may be characterised. It has to be admitted that yak to date, has better adaptability than any other hybrids in this harsh environment. The cross-breeding scheme cannot be expanded and / or it is not necessary to expand to the whole plateau. The systematic selection of yak breed and the *in-situ* conservation of a yak gene pool, therefore, must be carried out immediately, which will become an important basis for the sustainable development of yak husbandry;

- explore in depth the traditional strategies and indigenous knowledge of yak herders so that the best aspects of the traditional practices can be incorporated into modern improvement plans. Both cross-breeding and straight-breeding are important for pastoral development on the Tibetan Plateau. Technical support and investment should not only be limited to the field of cross-breeding, as the first purpose of the pastoralism in these remote areas should be subsistence rather than marketing in the forecasting future;
- conduct research on fodder and development of hay meadows for yak winter-feeding. If there is not enough foodstuff provided to yaks and / or their hybrids, the potential of milk, meat and hair production which is hoped for by development agencies, cannot be really elaborated;
- conduct research on the impacts of the marketing force on the improvement practices, breeding orientation and management systems. The forecast for the change of the marketing force and outlets is necessary for the steady and sustainable improvement scheme during the next five to ten years;
- raise the level of technical capacity through training and technical exchange in pastoral areas and to survey socio-economic problems associated with production or reproduction. The on-going privatisation in China has an impact not only on management of yak and land use patterns but also on the infrastructure and the direction of pastoral development. Any improvement scheme on livestock must be environmentally sustainable as well as politically sustainable (politically steady).

Conclusion

In the Tibetan Plateau many cross-breeding methods have been conducted in the last few decades, but few systematic schemes were implemented on the straight-breeding of yaks. Although the national selection criteria for yak breeds were set up in the 1980s, cross-breeding between yaks and cattle is still the only content involved in the most developed programmes. In operational opinions, straight-breeding should be largely promoted and the indigenous knowledge of herdsmen on yak selection should be combined into the future yak breeding programmes. Cross-breeding schemes should be limited to more favourable areas, such as agro-pastoral areas or the areas neighbouring in consideration of ecological adaptability of hybrids. The remote pastoral area should be dominated by yak stock when forecasting in the future. Even so, a cross-breeding scheme should

not be expanded on a large scale until the technical capacity of local communities is enhanced so much so that they can master the techniques for more intensive management, more fodder could be provided to winter raising and enough market outlets could be made available for animal products.

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Appendix 1

A brief introduction to Yak

People always associate the high and frigid range on the Tibetan Plateau with the yak (*Bos grunniens*), because it is one of the most important species of livestock found in the Himalayas and on the Tibetan Plateau, as well as in pastoral areas of north-western China, Mongolia and southern Russia. Yak is the multipurpose high altitude large mammal belonging to the *Bovidae* family under the tribe ruminantia, and the only one species of bovines that can adapt itself to the physical environment of the Plateau. Man said: "Without yak it is difficult to imagine the situation of animal husbandry in the Qinghai-Tibetan Plateau." This implies that it is impossible to separate the yak production with the climate of the Plateau, alpine pastures and the daily life of the Tibetan.

Nomadic yak breeding sprang up in the Tibetan Plateau as a result of the adaptation of the pastoral communities with a producing economy to specific ecological niches created by the simultaneous effects of various natural geographic, socio-economic and historical factors. Traditionally yak breeding patterns can be interpreted as the result of adaptive responses of organisms and societies to current pressures and specific historical processes. Archaeological evidence indicates that the earliest domestication of yak, sheep and goats occurred in various locations in the Tibetan Plateau about 5 000 years ago (Cai, 1989). Originally an aspect of broad spectrum village subsistence and then specialisation in its own right, this technology becomes prevalent in the Tibetan Plateau and its adjacent territories.

In the Tibetan Plateau most of the places lower than 4 500 m are unsuitable for cropping, except for the few river valleys in the south and east. Therefore, the extensive areas of rangeland, with the area of 167 million hectares are available for yak grazing. In 1996, it was estimated that there were about 14.5 million yaks in Chinese territories (including yak-cattle hybrids).

Yak enjoys the rare distinction of being the only large mammal that dwells in-between 2 500 to 6 000 m with ease and simultaneously produces work and products. The natural habitat of yaks has some distinct characteristics, such as rarefied air and scanty grass resources. The diurnal temperature fluctuation is very wide at high altitude. High altitude pastures above 4 000 m almost remain inaccessible in the winter season due to snowfall. During this period the yak herds descend down to a lower altitude (always below 3 500 m) for the winter grazing, where few sunny days occur in the

melting of snow and the grasses or shrubs are available for grazing by yaks. During the peak winters these areas also experience heavy snowfall but never remain under snow for a long period. Therefore, the features of the living area of yak are summarised as follows:

- high altitude (2 500-6 000 m);
- low temperature (annual mean temperature around and even below 0°C);
- great difference of diurnal temperature (above 15°C);
- low atmospheric pressure (below 110 mm mercury high); and
- alpine meadow, with dwarf shrubs but in good quality.

Yaks are endowed to live in the cold regions as they have some physiological and anatomical ramifications in comparison to other members of the bovine group. Since the result of natural selection of the special and harsh ecological environment, yaks have a very strong survival ability and form a serious function against the hard environment (Cai, 1989; 1992). Generally speaking, temperature is the single most important factor determining the distribution and stocking density of yak (Wu, 1997a). Yaks survive and perform adequately if the annual mean temperature is below 5°C and the average in the hottest month is not above 13°C. Subject to the availability of adequate grazing, the distribution and stock density of yak increases with altitude. However, altitude is of lesser importance than air temperature, because the relationship between altitude and latitude can be mediated through air temperature.

With the extensive rangeland, yak breeding remains important both for the subsistence of the majority of the rural population and for the entire economic system. In the absence of alternative opportunities for local employment of any significance, most people, mainly Tibetan, earn their livelihood from yak husbandry. For example, in western Sichuan the output value of pastoral livestock production approaches 54 percent of the Gross Agricultural Output Value (GAOV) as a whole. As extensive technical and economic reports mention, purchasing of animal products has generated no less than half the income since 1975. According to the statistics of the Provincial Animal Husbandry Bureau, 72 percent of milk, 45 percent of beef, 42 percent of bovines' skin and 34 percent of hair (including downhair) in 1995 came from the production of yak. Although the composition of livestock herds in different ecological regions are varied, yak is always an important means of subsistence and of productivity in all pastoral societies of western Sichuan, which contribute more than meat, milk and clothing materials. When associated with cropland they often contribute manure and traction. It is also common for yak to be used for transport and as a form of capital and security. In pastoral societies it may contribute blood to the diet and invariably it is used to build and maintain social relationships. Hides and skins are used for housing and water containers as well as for clothing and dung may be also used as fuel instead of manure. Different species perform different functions in different

livestock production systems. The functions which yak fulfills in a given situation derive from interaction between environment, human need and custom.

Over the centuries, yak herders have bred yaks and developed numerous local yak types, often recognised as distinct breeds with different characteristics. In China ten types have been identified, which include *Jiulong* Yak and *Maiwa* Yak in Sichuan, *Zhongdian* Yak in Yunnan, *Tianzu* Yak and *Gannan* Yak in Gansu, Plateau Yak and *Huanghu* Yak in Qinghai, Alpine Yak and *Yadong* Yak in TAR (Tibetan Autonomous Region), and *Bazhou* Yak in Xinjiang (Cai, 1992). However, there is little scientific evidence available on the genetic variation that exists between these different breeds. The existence of different breeds may be the solution to developing a yak genetic conservation policy and new genetic programme for commercial yak raising

Different yak breeds exist, for the most part, in different areas where yaks are raised. To date, no proper genetic comparison has ever been made between these different breeds in terms of their performance and general attributes (Miller *et al*, 1997). It is not known to what extent the breeds differ genetically. All that is known is that they appear to differ in their general appearance. It is necessary, therefore, to measure performance, survival and reproductive capacities among the different breeds to determine how much one breed differs from another. Yak breed comparisons and the crossing of yak breeds could be very valuable for identifying yak genetic diversity and would provide a scientific basis for yak genetic conservation plans and, probably more importantly, for the development of improved breeding plans for yak herders to follow (Wiener, 1997). This could eventually lead to improvements in yak performance and hopefully even ensure the long-term survival of the yak and the unique yak-herding culture which it supports.