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Interspecies Hybridization between Yak, *Bos taurus* and *Bos indicus* and Reproduction of the Hybrids (14 Dec 2000)

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Summary
Yak are crossed with *Bos taurus* and *Bos indicus* cattle, including common local cattle breeds (via natural service) and via artificial insemination of frozen-thawed semen from improved breeds (e.g. Holstein Friesian). Female hybrids reach puberty and mate a year earlier than pure yaks. Nonpregnant F1 females usually have several estrus cycles in the same season and will generally calve every year. Calf survival is similar to that of the pure yak, however, abortion and dystocia are more frequent. Male hybrids are sexually active but produce no spermatozoa (the cause is uncertain) and therefore are sterile. Sperm production does not resume until at least the third backcross (15/16 yak or cattle), and often not until the fourth backcross. The F1 hybrids generally grow faster and larger than the pure yak, with production of milk and meat exceeding that of pure yak and usually exceeding that of local cattle breeds.

Introduction
Hybridization between yak and cattle of other species is recorded in ancient historical records. The cattle originally used were local breeds (generally referred to as "yellow cattle" (*Bos taurus*) in China) and both *Bos taurus* and *Bos indicus* (Zebu) cattle elsewhere. Although this practice continues, more recently improved breeds of cattle have also been used (facilitated by AI of frozen-thawed semen). However, due to the reproductive isolation of different animals and the low conception rate of hybrids produced from yak and other cattle breeds, crossbreeding between yaks and cattle is limited to only the F1 and F2 generations. The F3 generation (containing about 12.5% yak genetics) have difficulty surviving in the high-altitude areas (above 3000 m) in Qinghai-Tibet Plateau and therefore are seldom produced. Since AI is inevitably restricted to more accessible areas and maintenance of improved breeds is difficult and expensive, most crossbreeding programs use locally available cattle.
Although crossbreeding and the infertility of male hybrids have been extensively studied, there are no clear conclusions. The ability of hybrids to produce sperm increases gradually with successive generations. Although crossbreeding is generally restricted to the F1 and F2 generations, sperm production does not resume until at least the third backcross (15/16 yak or cattle), and often not until the fourth backcross.
Systematic crossing of yak with other cattle has been recommended and practiced for many years; ancient documents indicate that yak have been crossed with common cattle (*Bos taurus*) for at least 3000 years. Documents from 11th century China (Zhou dynasty) suggest that crossing of yak with cattle by the Qing people gave benefits now recognized as heterosis. From the earliest times, the name "Pian Niu" (and other variants) has been used to describe these hybrids. These crosses find a special niche with herdsmen, usually at a somewhat lower altitude than typical yak country. Crossbred females are an important source of milk and dairy products. Since males cannot be used for breeding, they are used as draught animals or are slaughtered for meat. These hybrids are very suitable for work as they are easily tamed and have better heat tolerance than pure yak.
Yak females are usually mated to bulls of local cattle breeds. This is regarded as the normal hybridization; in China, the F1 is called "true Pian Niu" (or simply "Pian Niu"). The reciprocal cross (female cattle and a yak bull) is also practiced and regarded as "counter-hybridization" (progeny are called "false Pian Niu"). These hybrids are produced mainly in the cattle-producing, cold areas of Gansu and Sichuan and are used

mainly for draught purposes (milk production is low).
Semen from improved breeds of cattle, such as Holstein Friesian and Simmental have been used to breed yaks but are not popular due to the lower survival of the hybrids. Recently, semen from Hereford, Angus, Simmental, Limousin and Charolais have been used extensively to breed yak females. In Nepal, *Bos indicus* (Zebu) cattle are crossed with yaks. It has been suggested that crossing yaks with Highland cattle (from the United Kingdom) results in hybrids with superior productivity.
Experiments were conducted in the 1920's and 1930's (at Buffalo Park, Wainwright, Canada) to develop a meat animal for their cold northern conditions. In these experiments, a small number of crosses were successfully made between yak males and female American bison and half-bison (bison x cattle cross) [1].

Production Performance of Hybrids
The birth weight of hybrids produced by mating yak females and local Chinese (yellow cattle) bulls can be as much as 50% heavier than pure yak calves [2-5]. Reports from other countries also suggest a substantial increase in birth weight of hybrids resulting from crosses of yak females and males of a local breed of cattle (e.g. increases of about 15% and 30 - 40% for Buryatia [6] and Mongolia [7], respectively), with the extent of the increase dependent upon the types of yak, breeds of local cattle used, and husbandry practices.
A number of experiments have shown that carcass composition of hybrids derived from mating yak with both local cattle and different improved breeds did not differ from pure yak; differences in carcass weight were detected but were attributable to differences in live weight at slaughter. However, it is apparent from these experiments that there is potentially a very large difference between Yaks and F1 hybrids (of improved breeds) in growth rate during the first and second summers of life. Consequently hybrids weighed about 50% more than pure yaks when both were slaughtered at 17 months of age. Furthermore, hybrids attained an adequate degree of finish (fat deposition) and had a proportionately greater yield of meat than yaks of the same age.
Milk yield of hybrids of yak with local *Bos taurus* or *Bos indicus* cattle or improved *Bos taurus* breeds is very dependent on the breeds used, location and conditions. In general, improved Pian Niu produce the most milk, local Pian Niu are intermediate, and pure yak produce the least.
First crosses of yak females mated to bulls of local cattle breeds (Pian Niu), and the reciprocal crosses, are widely used for draught, both for plowing and as pack animals. Hybrids produced by mating yak bulls to female (local) cattle (false Pian Niu) are used mainly for plowing.

Reproduction and fertility
Female hybrids, first-cross and backcross generations, have normal fertility. Males, however, are sterile until there have been several generations of backcrossing (to either yak or common cattle).

F1 Female Reproduction
Estrus
Estrus in the F1 hybrids is seasonal and affected by climate and nutrition (similar to the yak) but puberty occurs approximately 1 year earlier than in yak. Therefore, F1 females are usually mated at 25 - 28 months of age (in the third warm season of their life) and they calve for the first time at about 3 years of age. Mating a year earlier does, however, occur under more favorable conditions and was noted (many years ago) as a potential advantage in Kazakstan [8].
During the breeding season, female Pian Niu usually display estrus from May to November, with a peak in July and August (about 1 month earlier than pure yak under the same conditions). Estrus can occur several times during the breeding season if the crossbred female has not been mated or is not pregnant; this is different from the majority of pure yak cows in China (although repeated displays of estrus in yak are more common in other countries, e.g. Mongolia). Furthermore, signs of estrus in the F1 female are more obvious than in the pure yak.
Cai examined (by rectal palpation) 211 F1 females in estrus and reported that 185 had normally developed follicles, a proportion slightly higher than in contemporary yak [9]. Nonetheless, in ordinary mass mating with yak bulls, the conception rate (75%) of Pian Niu cows was somewhat lower than that of yak at the same location [9]. However, in a specific trial conducted by Cai using yak bulls, 155 female Pian Niu F1 had a conception rate of 70% at their first estrus of the breeding season, but a further 25% conceived at a second estrus. With AI of frozen-thawed Holstein Friesian semen, the overall reproductive rate of the Pian Niu was substantially better than that of pure yak [9].
In a survey of 136 F1 females, 77 (56.6%) showed estrus, higher than the estrus rate in pure yaks. Of the 66 F1 females that did not calve in the current year, 63 showed estrus (95.4%); estrus was detected in 84.3 % of pure yaks under the same conditions. In the current year, of the 70 female F1 Pian Niu that calved

and were milked, 14 (20%) showed estrus (compared to a 36.6 % estrus rate in pure yaks). Perhaps the high milk yield (and twice-daily milking) of F1 females contributed to the lower estrus rate [10]. Generally, multiparous yak cows that produced F1 Pian Niu calves have a lower conception rate when hybridization mating is used.

Gestation Length

Cai [9] reported that the gestation length in crosses of yak with ordinary local cattle as 278.0±9.7 days for 110 F1 cows with male calves and 271.3±11.1 days in 98 cows with female calves. Denisov [8] reported an average gestation length of 282 days for F1 females mated back to Schwyz cattle bulls and 265 days for those mated back to yak bulls.

When frozen-thawed semen from a Hartford bull was used to mate F1 females, the gestation period was 278.6±4.12 days (n=25), and for F2 females, it was 282.6±7.8 days for female calves and 277.3±9.6 days for male calves, for an overall average of 269.0±10.6 days (gestation is 285 days for Hartford and 255 days for yak) [10]. The same semen was used to inseminate pure yak females and F1 Pian Niu from 1975 to 1978 and the results are listed in Table 1 [10].

Table 1. Reproductive performance of pure yak females and F1 females inseminated with frozen semen from one Hartford bull

Species	Number	Offspring	Conception		Calving		Survival	
			N^{o}	%	N^{o}	%	N^{o}	%
F1 Female	211	F2	161	76.3	146	90.7	131	89.7
Pure Yak	117	F1	46	39.2	31	67.4	30	96.8

Survival to 6 months of age is similar among F1, first Backcrosses (B1) and pure yak. Thus, relative to the yak, the F1 cross has a better overall lifetime reproductive rate, due to repeated displays of estrus (and opportunities to mate in females that fail to conceive) and a higher probability of calving every year.

Abortion and Dystocia

Due to genetic differences between yaks and other cattle breeds, there are placental abnormalities that may result in inadequate support of fetal development. Abortion occurs more frequently when yaks carry a hybrid fetus. In a survey of 5623 matings (to produce hybrids) in Hongyuan County, Sichuan, from 1976 to 1982, the abortion rate was 20.7% [10]. Although the causes of abortion have not been established, it is speculated that genetic differences, placental underdevelopment and environmental conditions such as cold weather and low oxygen content of the air may be involved.

Dystocia is more common with hybrid fetuses than yak fetuses. A survey from Hongyuan County in 1979 showed that of 1144 calvings, 32.8% required assistance (5% were delivered by laparotomy). Therefore, it is recommended that large females are used to produce hybrid calves. Furthermore, the incidence of hydramnios was 8.2%.

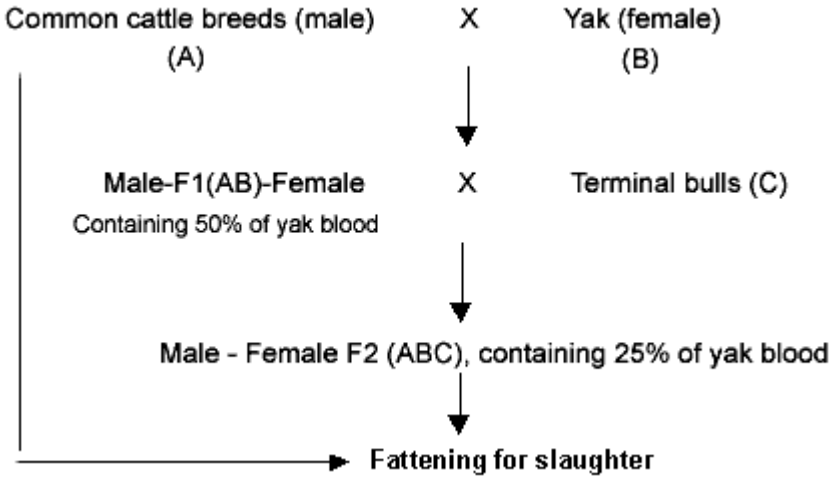
The external genitalia, libido, and mating behavior of the crossbred male are normal but there are no sperm in the seminal fluid. Therefore, the crossbred is a natural teaser bull. First and second backcross generations are also sterile. By the third generation of backcross (15/16 yak or cattle blood) some spermatocytes are usually present and the occasional male is fertile. Fertility is not assured until the fourth or fifth generation of backcross [11]. In practice, however, intact males of the backcross generations are rarely seen, since there is no good reason to produce them. Therefore, precise data on the proportions of bulls showing normal spermatogenesis in successive generations of backcrossing are not available.

The causes of sterility in hybrid males have been, and are still, the subject of much investigation and speculation. It is well established that there are no spermatogonia in the seminiferous tubules of F1 and early generations of backcrosses. Possible causes for this have been considered in the structure of the X and Y chromosomes; these structures differ in certain respects among crosses, pure yak and pure cattle [12]. In particular, the arm ratios differ, most notably for the Y-chromosomes. In a recent review [13], it was noted that the length of the Y chromosome and the relative lengths of the chromosomes vary among cattle breeds. Therefore, fertility of male yak hybrids might be restored by selecting a *Bos taurus* breed with Y chromosomes that are of similar length as those of the yak. A less likely explanation, advanced by Zhang [11], is that male sterility may be due to an imbalance at many chromosome loci (including autosomal).

There are differences among hybrids, yak and ordinary cattle in the proportions of different cell types in the anterior pituitary gland, resulting in reduced production of FSH in hybrids. However, frequent injection of FSH and LH intra-venously in well-fed crossbred calves increased libido but did not result in sperm production at 12 months of age [9].

Crossbreeding Policy

First crosses between yak and common cattle adapt well to the conditions in which they are used, displaying good characteristics of both parental types, including resistance to a harsh environment and improved productivity. Backcrosses compared to cattle, however, are less well adapted to the environment and their productivity is often lesser than in yaks, probably due to reduced heterosis. Therefore, it is common practice to dispose of these calves immediately after birth and subsequently milk their mothers. Due to the infertility of F1 male hybrids, they can not be used for reciprocal crosses or to develop new cattle breeds. Therefore, hybridization between yak and other cattle breeds are only used for economic crosses. In order to explore heterosis of interspecies hybridization and the hybrid could survive in the cold Qinghai-Tibet Plateau, static cross or terminal cross system is recommended and it can be expressed as:



Terminal crosses are characterized by using small-sized common cattle breeds (body size of F1 is large and it can be used to cross with large cattle breeds so that dystocia is reduced). Ternary crosses can be established by using two common cattle breeds and yak so that maximal heterosis could be achieved. The F2 have 25% yak blood; if they are crossed with common cattle, the resulting F3 generation could not survive in the cold alpine grassland (with more than 8 months of winter).

Limits to Hybridization

Poor reproductive performance in yak severely limits the number of female yaks that can be used for crossbreeding (if the numbers of pure yaks are to be maintained or perhaps increased). In practice, it has been found best to produce the F1 generation and then slaughter the F2 generation for meat. Since the males are sterile, only the F1 females can be backcrossed to yak or cattle bulls. However, reduced productivity (relative to the F1) makes the backcross generations commercially unattractive.

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