INTRODUCTION
The majority of milking buffaloes are reared in India (46 million), Pakistan (10 million), China (8.5 million) and Egypt (1.5 million). Despite their lower number in Iran (210,000), Italy (125,000) and Bulgaria (5,000), they are economically important. It is recognized that animal recording and selection is fundamental for the improvement of milk production. Although all governments have, to some extent, promoted and funded buffalo recording and breeding activities, political instability and lack of financing have not allowed long term strategies with many of the developing countries. In this paper we will examine how each country has approached the genetic improvement of buffalo: nucleus herds from which semen and calves are spread out on field or the extensive milk recording within a Herdbook including as many animals as possible. A particular emphasis will be given to the Italian case, by detailing the problems that were found and how these problems were at least partially overtaken.

ITALY
Background
In the last thirty years, buffaloes in Italy have more than tripled in numbers, i.e. from 80,000 head in 1974 to 265,000 in 2004 (Borghese, 2005). The reason for this increase is that from a rustic triple-purpose animal, buffalo became a dairy purpose animal. Increased demand for the mozzarella cheese, both on the national and international market, together with milk quotas (i.e. taxes on surplus cow milk production) imposed by the European Union, have favoured the increase of buffalo production. The Italian Ministry of Agriculture is in charge of milk recording and selection activity in collaboration with the Italian Breeder’s Association (AIA) and the Buffalo Breeders’ Association (ANASB). From July 2000, the ANASB in charge of keeping the Herdbook and the selection activity. Before this time, selection activities were started by the AIA. Animal production recording started in 1997, following the procedures used for the dairy cows (A4 method). Table 1 shows the increase in number, as well as in milk yield, of recorded buffaloes in Italy over the years.

Buffalo research
During the 80’s, the typical dairy product provided by buffaloes – mozzarella, once available only on the local markets of some areas of Southern Italy, was launched all over the country and it was liked by the consumers all over Italy and abroad. In this way, the rustic triple-purpose animal, reared in the swampy lands of Southern Italy, reclaimed and improved through the Agrarian Reform of the Post-War period, received great attention from scientists. The spreading of buffaloes all over Italy, accompanied by milk recording quantitatively and qualitatively, is evident from Table 1: in 1977 buffalo herds were settled only in two Italian districts but in 2004 in 35 districts. A good deal of funding in animal production was therefore given for research on buffalo. The major projects dealt with the most critical problems of this species: nutrition and reproduction. It became apparent that buffalo was different from the dairy cow. Feed and energy conversion system turned out to be the opposite of the dairy cow,
because in dairy cow it was demonstrated that milk fat decreases for higher energy levels of the diet, while in buffalo the energy level of the diet positively affects milk yield, as well as fat and protein content (Bertoni et al., 1991; Bartocci et al., 2002). Also mozzarella yield is highly affected by the energy level of the diet. The new findings allowed to define appropriate diets for buffalo feeding, and the results in the improvement of milk yield were soon consistent. In fact, the increase in milk production (Table 1) obtained during the period 1986-1995 (21%) is to be considered extremely high, because it was obtained despite of a huge number of new animals joining of the milk recording system (in 1995 they are over twice than in 1986). During the period 1995-2004 milk production increased by 10.9%, while buffalo population doubled in numbers. It is interesting to note (Table 1) that milk fat contents also increased gradually and considerably (+ 2%) since the beginning of the recording activity. The increase in milk and fat yield was mainly due to the better management and feeding conditions in which buffaloes were reared.

Table 1. Basic statistics on buffalo productivity from the beginning of the recording activity (AIA; ANASB).

<table>
<thead>
<tr>
<th>Year</th>
<th>N. herds</th>
<th>N. districts</th>
<th>N. recorded buffaloes</th>
<th>Milk yield (standard lactation 270 days)</th>
<th>Fat content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>kg</td>
<td>STD % STD</td>
</tr>
<tr>
<td>1977</td>
<td>40</td>
<td>2</td>
<td>1451</td>
<td>1608</td>
<td>435 6.43</td>
</tr>
<tr>
<td>1982</td>
<td>103</td>
<td>5</td>
<td>4558</td>
<td>1720</td>
<td>463 7.73</td>
</tr>
<tr>
<td>1986</td>
<td>128</td>
<td>8</td>
<td>7678</td>
<td>1627</td>
<td>521 8.33</td>
</tr>
<tr>
<td>1990</td>
<td>168</td>
<td>14</td>
<td>9884</td>
<td>1893</td>
<td>529 8.10</td>
</tr>
<tr>
<td>1995</td>
<td>230</td>
<td>30</td>
<td>15378</td>
<td>1970</td>
<td>555 8.30</td>
</tr>
<tr>
<td>2000</td>
<td>284</td>
<td>35</td>
<td>22445</td>
<td>2145</td>
<td>599 8.28</td>
</tr>
<tr>
<td>2004</td>
<td>294</td>
<td>35</td>
<td>26288</td>
<td>2184</td>
<td>610 8.06</td>
</tr>
</tbody>
</table>

The other major constraints to buffalo improvement were the delayed puberty compared to dairy cows, and the silent estruses. The paternity issue is very critical in Italy because of the large herd size usually under natural mating system.

Buffalo research during these years focused, therefore, on reproductive studies (Terzano et al., 1996). Thus the age of the first delivery decreased by 30 days during the last twenty years (1981-2004). To define the optimal conditions to perform artificial insemination, researchers have conducted several studies on the physiology of ovulation, including measuring of blood LH and progesterone levels variation during the estrus period (Barile et al., 1998). They tested protocols for estrus synchronization with intra-vaginal appropriate devices, to reduce the failures in pregnancy (Barile et al., 2001).

Artificial insemination

Until 1986, breeding was performed only through natural mating. Artificial insemination (AI), which has been fundamental for the genetic improvement in all dairy animals, has not been adopted by many buffalo breeders. However, more and more farmers are getting interested in AI every year. Thanks to the flourishing of the research on buffalo reproduction, AI started in private farms and the basis was set up for implementing progeny testing trials (Zicarelli et al., 2005). It is estimated that now (2005) the percentage of artificially inseminated buffaloes is around 5%. Scientists have proposed, as the optimal method to reduce pregnancy failures, estrus synchronization with intra-vaginal appropriate device, followed by progesterone injection (Barile et al., 2001; Zicarelli, 2003). This system is now usually applied in a few herds, and brings in the advantage to concentrate calvings in the season when milk demand is higher, therefore milk gets a better market price. Pregnancy rate through this system ranges
between 45 and 64% (Barile et al., 2003; Barile et al., 2004). However, the cost of such system does not allow the application on very large basis. The use of a teaser bull for heat detection has been suggested in the past; however, this practice is now limited to the few herds where the owner himself performs the inseminations. In fact, due to the variability of the duration of estrus, more than two inseminations could be required at each estrus, with subsequent high veterinary costs. Because motor activity of a female remarkably increases during the heat, but such increase cannot be visually detected by farm operators, podometers have been used experimentally in a buffalo herd in Italy, and demonstrated good feasibility for heat detection. In fact, the rate of conception after podometer detection was 40%, with average number of 1.3 inseminations/female. The accuracy of this method expressed as number of detected heats/total of podometer signals was 75% (Di Palo et al., 2001).

**Progeny test**

In 1987, AIA started progeny testing trials that were based on the following principles: put on each testing cycle 12 bulls, so to produce 5,800 semen doses each; 800 doses should be used for the campaign and the remaining to be stored. Each bull was expected to inseminate 200 females (2 inseminations/female), so to have at least 15 daughters/bull ending their first lactation. In this sense, pregnancy failures, embryo mortality, sex ratio at calving, and mortality of the daughter before ending the first lactation were taken into account. Forty-six young bulls were progeny tested during six campaigns performed by AIA, from 1987 to 1995 and seventeen positive bulls were issued for breeding.

From July 2000, the ANASB took charge of all the selection activity, including the progeny testing trials. In order to be a candidate to progeny test, a young bull must fulfil the following criteria: be son of Bull Dam which means: minimum 80 scores (Good +) in morphology linear evaluation; one 270 day officially recorded lactation with minimum values of: 3,100 milk kg; 7.7% fat and 4.5% protein; one registered generation of paternal and maternal ancestors and at least the grandmother enrolled in the Herdbook; the Bull Dam must also have a genetic evaluation with positive PKM selection index (see later) falling at least in RANK 80. Candidate young bulls are further submitted to morphology evaluation by breed experts. Every candidate bull goes first to a quarantine centre for veterinarian controls. Then the young bull is taken to semen collection unit (there are 3 of them in Italy) where functional characteristics of the collected semen are analysed. From each bull on the test, 1000 semen doses are collected to inseminate approximately 400 females.

Three progeny testing cycles were performed from 1998 to 2005. In these cycles 10 bulls were put on-test; over 14,000 semen doses were produced and more than 3,000 buffaloes were inseminated.

**Genetic evaluation**

Twice every year, bull, cow and heifers genetic merit for milk, mozzarella yield (PKM), fat and protein percent, fat and protein kg, are calculated with an animal model. Because more than one bull in each mating group is used commonly, genealogy registrations of the buffaloes included in the animal model are not complete. Since 1993, paternity test through DNA markers is available for Herdbook farmers and compulsory for registering the new born in the Herdbook. However, because all lactations starting from 1980 are processed in the animal model, only for 0.1% of the buffaloes of which the genetic merit is calculated the sire is known. The problems related to paternity in buffalo always existed and are difficult to solve; therefore animal registration is sometimes partial; at the same time, it is not possible to wait till the paternity matter is solved before implementing genetic improvement programmes. The genetic importance of the females is therefore much higher than the males. At the same time, ANASB is working hard towards obtaining a better reliability of the genetic merit estimation.
The most recent record input file of the genetic evaluation procedure (September, 2005) was composed as follows:

- Number of lactations: 268,054
- Considered years: 1980-2005
- Number of herds: 487
- Number of buffaloes with at least one lactation record: 93,954
- Number of AI sires: 67
- Number of Natural Mating sires: 442

The genetic merit of the progeny tested bulls is therefore recalculated at each round of data processing through the lactations of their subsequent progenies. The genetic merit of the natural mating bulls is also calculated provided that the minimal requirements of number of daughters and connectedness with other herds through progeny and half-sibs are satisfied. The need of knowing the genetic merit of the natural mating bulls is strongly perceived by the big farmers (over 90 cows). Young animals (heifers and male calves for natural mating) are also included in the model and their genetic merit is expressed as a pedigree index.

The most important breeding goal for the Italian buffalo is mozzarella yield, and the genetic merit for this trait is calculated in a single-trait animal model as well as for the milk components (kg and percentage). Mozzarella yield (kg) takes into account the milk production of the 270 day lactation, together with fat and protein content, weighed by coefficients that consider the effect of milk components on this trait, as follows:

\[
\text{Mozzarella yield (PKM) = Milk (kg) \times \left\{ \left[ (3.5 \times \text{protein}\% + 1.23 \times \text{fat}\%) – 0.88 \right] / 100 \right\}
\]

Results are published in special catalogues that are produced by ANASB twice yearly. In the catalogue, the top 1% of Italian buffalo cows with the highest genetic merit for mozzarella and milk production are listed, as well as the genetic merit of the positive AI bulls.

OTHER COUNTRIES

A specific seminar on animal recording for improved breeding and management strategies for buffaloes, jointly organized by FAO and the ICAR in the year 2000 (http://www.icar.org/docs/technical_series/tec_series_04_bled_buffalo.pdf), clearly identified the major constraints affecting the implementation of the milk recording activity. These can be briefly summarized as follows: 1. Lack of finance; 2. Reluctance of farmers to reveal to other people the levels of production of their animals; 3. Identification of the animals. 4. Recording costs. These constraints illustrate why the percentage of recorded buffaloes in countries where buffaloes seem to be more important than cattle is below 1%.

INDIA

The National Dairy Development Board (NDDB) was the promoter and is the executor of the whole recording and selection activity. The NDDB was created to promote, finance and support producer-owned and controlled organizations. The best results were obtained in the state of Gujarat where NDDB started this activity in 1987. In 2000, 2.5 million buffaloes were documented by milk recorders employed by the village cooperative societies. These recorded buffaloes are all raised on smallholdings of 1-5 animals, which means over 800,000 recorded herds, and from these herds every year a total of 40 young bulls are selected for progeny testing and sent to the AI station. In the region, there are three natural breeding stations controlled by the cooperative. Forty percent of the 2.5 million buffaloes are served through AI, while the remaining sixty percent are taken to the breeding station. The three breeding stations belong to the Dairy Farmers’ Cooperative Union, a non-governmental organization. They keep about 260 bulls yearly, of an average age of six years. The milk genetic merit of each bull is
estimated on the basis of the milk production of 30 to 50 daughters per bull. An animal model is used for the calculation. Two of the three AI stations are also owned by the Dairy Farmers’ Cooperative Union; they keep 105 bulls which produce 730,000 semen doses a year. Ninety percent of the bulls are progeny tested or born from progeny-tested bulls, while the remaining are new on-test bulls. There is an additional AI station owned by an international non-governmental organization. It keeps 155 bulls, producing altogether 410,000 semen doses a year. Ninety-five of them are progeny-tested bulls or bulls born from progeny-tested bulls, while the remaining are new on-test bulls. The size of individual smallholdings does not permit the upkeep of their own breeding bull; this is the reason why the AI stations are frequently employed. The majority of farmers is given only one semen dose per buffalo; few of them request two doses. Conception at the first oestrus is 41 percent and per year is 2.46 inseminations per conception.

PUNJAB (PAKISTAN)
The milk recording system and selection activity have been implemented by the Livestock and Dairy Development Department of Punjab, through the Livestock Production Research Institute, Bahadurnagar until the inception of Buffalo Research Institute at Bhunikey, Pattoki (District Kasur) in 2005. About eight thousand Nili-Ravi buffaloes are milk recorded in seven large herds belonging either to the research institutes or to the army dairy farms, as well as in 27 field recording centres, where buffaloes in smallholdings of 5 to 20 animals are involved in the milk recording set up. The new institute plans to record twenty thousand buffaloes for its progeny testing and artificial insemination program. Average milk production (year 2000) was 1,823 kg (257 days) in the registered population and has improved over the years. Elite buffaloes have been reported to produce between 3,000-5,000 kg per lactation. Institutional herds are recorded weekly while recording at farmer level is on monthly basis. Fat and protein contents are not recorded. In the Punjab province, about 10% buffaloes are covered through AI. However, at the government livestock farms, 100% percent of females are inseminated by frozen semen from proven or on-test bulls. For bull selection a progeny-testing programme started in 1980, where high pedigreed bulls are selected on the basis of the milk production performance of their daughters. Government livestock farms are the principal centres for bull production. More than 300 bulls have so far been progeny tested. In Punjab, semen is produced and stored at Semen Production Units at Qadirabad (Sahiwal), Kalurkot (District Bakhar) and Karaniwala (District Bahawalpur) under the Directorate of Breed Improvement of Punjab.

EGYPT
The Cattle Information System/Egypt (CISE) of the Cairo University records now (2005) about 330 small (one to five animals), 27 medium (six to 20) and 22 large herds. The activity started in 1989 and increased exponentially, extending to 13 governorates. Milk test technicians are part-time staff employed by CISE. The central processing unit is composed of 6 staff including computer technicians and secretary. All data are centrally processed and monthly herd summaries are given back to the enrolled farmers at each monthly test. Information includes individual milk yield as well as suggestions for farm management regarding reproductive practices. In the case of small farmers (one to five animals) the basic unit is the village, each village having a milk test technician who works as the link between CISE and the single farmers. Calculation of the genetic merit of recorded buffaloes and breeding bulls is in progress. CISE has also established a nucleus herd of 30 buffaloes in Cairo with the purpose to produce calves and semen of higher genetic merit to spread out in the country.

In parallel to CISE, the Animal Production Research Institute (APRI) of the Ministry of Agriculture and Land Reclamation (MALR) owns four State buffalo farms (800 animals
altogether), for research purpose. In one of these farms (Kafr ElSheikh) a nucleus herd was started in 1997 with 200 breedable females. At each generation, nucleus size increases because only the worst yielding females are culled. Bulls of higher genetic merit are used to produce semen or for natural breeding stations, never used again in the nucleus.

AI is still employed at a very limited extent. It is used in 1% of the medium to large herds. There are six AI stations owned by the Government and one by the University of Cairo, possessing a total of 70 bulls. On the other hand, there are six breeding stations with a total of 60 bulls with an average age of five years. These stations belong either to APRI or MALR. All smallholders (1-5 animals) take their buffaloes to the breeding stations, and 20% of the medium-size (6 to 20) owners, too. In bigger herds, breeding bulls are mainly raised from their own male calves although 20% of them buy adult buffaloes (two to three years) from different owners.

IRAN
In Iran milk recording and the selection activity is implemented by the central government through the Animal Breeding Centre of Karaj. The recorded buffaloes are 6.5% of the total population (2004). Besides the official recording system provided by government technical staff, there is a semi-private system of recording performed by the farmer himself and by the staff of the local cooperative. In both cases, executive operations are supervised by the Animal Breeding Centre. The milk recorded herds are therefore provided with a wide set of information on the productivity of their buffaloes and breeding values of males that are centrally calculated from the productions of their daughters and related females. The semi-private system is more popular in the small herds (1-5 animals) where 7,100 buffaloes are milk recorded.

There are no breeding stations in Iran, but two performance testing/AI stations, one in West Azerbaijan (Jabal station), keeping ten bulls and the other in Kuhzestan with a capacity of 50 bulls. Bulls are pre-selected by provincial experts based on maternal performance and body type and then taken to the station at the age of between 6 and 18 months. Genetic merit of these bulls is estimated by an animal model which includes milk and fat yield, as well as body type parameters. Twenty thousand semen doses are produced yearly by the Jabal AI station. Artificial insemination is still performed at a low level, since the activity only started in the year 2000; it is estimated that about 200 recorded buffaloes are offered AI yearly; two insemination at each oestrus are always offered, the conception at the first oestrus being 50%.

Smallholders (1-5 animals) possess the majority of buffaloes in Iran (72 %), medium-size farmers (6-20 animals) have 23%, and bigger farmers (over 20 animals), have 5%. Generally, small-medium holders grow their own breeding bull from their stock (50%) or borrow a bull from a neighbour (10%), but 40% of the buffaloes are left to be bred in village fields by unknown bulls. The big farmers either raise their own breeding bulls or buy (15%) a bull from another farm with proven milk genetic merit provided by the Breeding Centre.

BULGARIA
Milk recording and selection activity in Bulgaria is promoted and executed by the Regional Agency for Selection and Reproduction with scientific and technical support from the Agricultural Institute, Department of Buffalo Breeding, Shumen.

The majority of buffaloes (3,976 i.e. 80% of the total population) are reared in small herds (1-5 animals); in this herd-size class only 300 buffaloes are milk recorded. Consequently, no information is available to these farmers for improving buffalo productivity. Ninety percent of the farmers leave their buffaloes to be bred in village fields; however, five percent of them make use of the governmental breeding station. Artificial insemination is used for 5% of the
buffaloes among medium-size owners (6 to 20 animals), who also use the breeding station. In addition there are 10 larger herds (20 to 500 animals). In these herds AI is done in over 70 percent of buffaloes and a proven genetic merit bull is purchased from other owners in 25% of cases. There is one breeding station in Bulgaria, owned by the government, possessing 3 to 4 bulls on an annual basis. The genetic merit of these bulls is estimated using a BLUP animal model developed from the records of daughters and related animals. These calculations are performed by the Agricultural Institute, Department of Buffalo Breeding, Shumen. In addition, there are two AI stations possessing four bulls, which provide 1,320 semen doses every year, of which 1,050 semen doses are from proven bulls. Buffalo are offered two or more inseminations at each oestrus; the conception rate at first oestrus is 45 to 55 percent.

CONCLUSION

Performance recording of buffaloes in most of the buffalo raising countries is still limited to institutional herds. This is mainly because buffalo is raised under low input extensive system and herd size is generally low with the exception of buffalo colonies around big cities in some countries. Buffalo population is likely to grow in future because of a continuous preference for its products and its role in the agrarian economies of these countries. Genetic improvement programs are expected to expand and such expansions will be triggered by buffalo farmers’ organizations. The smallholder subsistence production is likely be the mainstay in many livestock production systems. Role of buffalo will become even more important in the future. Cattle breeding technologies have grown at a fast pace in the last decade but these innovations need to be augmented for buffalo improvement too. Only country level initiatives for buffalo development would be sustainable. Collaborative projects may be of help in capacity building for research and development to benefit buffaloes and buffalo farmers.

REFERENCES


