Indian Journal of Animal Sciences 67 (8, Special Issue) : 713-719, August 1998

Buffalo breeding research in India

V K TANEJA[1]

Indian Council of Agricultural Research, Krishi Bhavan, New Delhi 110 001

Received : July 1997

Key words : Breeding policy, Breed, Buffalo breeding

The domestic or water buffalo *(Bubalus bubalis)* belong to the family bovidae, sub-family bovinae, genus *Bubalus* and species *arni.* Buffaloes are believed to have been domesticated around 5000 years ago in the Indus Valley. The domestication of swamp buffalo took place independently in China about 1000 years later. The movement of buffaloes to other countries took place from these two countries.

The water buffalo can mainly be classified as river and swamp type. They belong to the same species but have different habitats. Swamp buffalo has 48 chromosomes, the river 50 and they interbreed and produce fertile progeny. The swamp buffalo, mainly a draught-cum-meat animal, is found in eastern half of Asia. The river buffalo usually has curled horns and is found in western half of Asia, Brazil, parts of the formerly USSR, Italy and a few east European countries. River buffaloes are docile and have specially been developed for milk production with high fat content in Indo-Pak subcontinent.

BREEDS, THEIR DESCRIPTION AND EVALUATION

Both river and swamp type buffaloes are available in India. Swamp buffaloes are found in parts of Assam. The river buffaloes are distributed throughout the country.

Around 65% of the river buffaloes are *desi* type and do not belong to descript breeds. Important buffalo breeds are Murrah, Nili-Ravi, Surti, Jaffarabadi, Bhadawari, Mehsana, Godawari, and Pandharpuri. Mehsana and Godawari breeds have been evolved through crossing of Surti and non-descript buffaloes with Murrah in Gujarat and coastal Andhra Pradesh respectively. Bhat and Taneja (1987) described characteristics of buffalo breeds. On the basis of body size and weight, Murrah and Nili-Ravi buffaloes could be classified as large, Surti and Bhadawari as medium, and Kundi as small sized breeds. Breeding tract of Nili-Ravi has gone to Pakistan and only a few thousand animals of this breed are now available in India. Murrah has been used as a major improver breed for grading up non-descript buffaloes throughout the country. This breed has also been exported to a number of south east Asian countries, Australia, Mediterranian and Latin American countries to be raised as purebreds and in crossbreeding with swamp and local dairy breeds.

Description of breeds initially was done between 20's and 30's by imperial civil and military officials and their important characteristics were recorded in the Gazette of British India. These descriptions were based on information from organised farms and not on extensive surveys and thus do not cover the extent of variability present in these breeds. It is therefore imperative that animal genetic resources should be re-evaluated. The National Bureau of Animal Genetic Resources, Karnal, has taken up the characterisation including generation of population statistics of breeds in their native environment through surveys. Evaluation and characterisation of Bhadawari and Toda buffaloes have been completed and that for Nili-Ravi, Jaffarabadi and Pandharpuri buffaloes is in progress. Population of Bhadawari and Surti buffaloes has declined due to crossing of Bhadawari and Surti buffaloes with Murrah to increase milk yield. Toda buffaloes are facing extinction because of large-scale crossing with Murrah. Immediate steps, therefore, need to be taken to reverse this trend and develop breeding strategies which will conserve the affected breeds. Herd registration programmes for Surti, Murrah and Jaffarabadi are significantly contributing to improvement and conservation efforts. Genetic characterisation of these breeds is in the preliminary stages of investigation.

ANALYSIS OF BREEDING POLICY

A number of schemes were initiated on breeding of buffaloes since the inception of the Indian Council of Agricultural Research in 1929 (then Imperial Council of Agricultural Research). In the middle of sixties, it was decided that breeding of livestock should be organised on scientific lines. Accordingly, Department of Agriculture in 1962 had set up a working group to review the cattle and buffalo breeding policy. The working group reviewed the breeding policy fol-

[1]Present address : Assistant Director General (AP and B).

lowed in each state and recommended a policy for achieving increased milk production in Indian cattle/buffalo. The buffalo breeding policy envisaged (a) selective breeding for conservation and improvement of buffalo breeds in their home tracts, and (b) grading up of non-descript buffaloes with recognised buffalo breeds. Murrah, Nili-Ravi and Surti were used in grading up non-descript buffaloes. Although no scientific evaluation of the grading up schemes have been made, large increase in share of buffalo milk overtime suggested the effectiveness of grading up schemes.

In the defined breeds, the selection in the initial years was done through culling of low yielders and selection of bulls on the basis of body confirmation and dam's milk yield. Government farms for important buffalo breeds with herd size of 300 breedable females and 10 bulls were established for production and testing of bulls for improving milk yield in them. The results of these studies were not encouraging due to small herd size, poor accuracy of sires breeding values and non-availability of semen freezing facilities at most of the farms. The genetic gains in milk yield revealed highest contribution from dam to son path (82-84%) and dam to daughter path (11-15%); contributions from sire to son and sire to daughter path were almost negligible. Apparently, the emphasis during selection both of cows and buffaloes was mostly on their dam's performance. This was expected in the absence of progeny testing. Small herd size, poor economic status of the farmers and poor spread of AI have been the major hindrances in taking up the performance recording and progeny testing in buffaloes in the field.

BREED PERFORMANCE AND GENETIC PARAMETERS

Various research schemes were initiated to answer specific questions pertaining to breeding and production efficiency parameters. These have been critically analysed to study variations in performance potential of the breeds, evaluate estimates of genetic parameters, selection criteria developed and improvement in methodologies to get precise estimates. A large body of the data were screened to generate the range of averages reported. Performance potential of the defined breeds is based on the performance in the organised farms and records on their performance in native environment are hardly available. A large body of data were screened and range reported. Selected references have been given as these would be too many. In performance parameters large variations were due to differences in location, management inputs, periods, genetic variation between herds etc.

Body weights and growth

The study of body weights at various ages provides a measure of growth and size and reflect the suitability of breed or strain to a particular eco-system and is important from the point of view of early maturity and general adaptability.

The birth weight in various buffalo breeds varied between 26 and 41 kg. Month/season, year/period, sire and sex significantly influenced birth weight (Misra *et al.* 1970, Nauliyal and Bhat 1979, Basu and Rao 1979, Vijai *et al.* 1993). Weight and age of dam at calving also influenced birth weight (Misra *et al.* 1970, Basu *et al.* 1978). The birth weight is largely influenced by maternal environment and has low heritability –0.16 - 0.32 (Sreedharan and Nagarcenkar 1978, Basu and Rao 1979, Vijai *et al.* 1993). The phenotypic and genetic correlations of birth weight with body weights up to first calving , age at first calving, and milk yield were negative or low (Marwaha 1974, Johri and Bhat 1979b, Vijai *et al.* 1993), thus suggesting that birth weight cannot be used to predict the mature body weight, age at calving or milk yield.

Examination of body weights across the breeds revealed that Nili-Ravi had higher weights at 3, 6, 12 and 24 months followed by Murrah while Surti had the lowest weights at all ages (Murdia and Chaudhry 1984, Sharma and Basu 1984, Tiwana *et al.* 1985, Vijai *et al.* 1993). The weight at first calving ranged between 335 and 525 kg, it being highest in Murrah (Basu *et al.* 1984) and lowest in medium sized buffaloes (Tailor *et al.* 1990, Vijai *et al.* 1993). The heritability estimates for body weights from 3 to 24 months were moderate (0.40 - 0.49) while those for weight at 36 months and weight at first calving were low being 0.20 and 0.16 (Nautiyal and Bhat 1979). The phenotypic and genetic correlations among adjacent body weights, in general, were high. The moderate to high heritability estimates for body weights at various ages and positive correlations among them suggested that these 2 facts should be utilised in formulating the breeding plan by giving appropriate weightage to body weights in the selection criteria so that higher body weights/growth rates leading to early maturity could be achieved. It would be essential to use sequential selection for body weights at various ages for young bulls and heifers.

Growth in general was linear from birth to 36 months. The average monthly gains across the breeds varied between 10 and 12 kg and that the growth rate was maximum between birth and 12 months. Observations on body weight gains suggested that period up to 1 year of age could be economically utilised in feed lot for obtaining maximum growth rate. It seems that present potential of the species is around 500 g/ day under medium inputs and 1 000 g under high input. This can be improved further through selection and use of fast growing males.

REPRODUCTION

The reproduction traits generally studied are age at oestrus, number of services per conception, number of calves produced per unit of time, age at first calving, service period, dry period and calving interval. Some of these parameters have been used to measure the breeding efficiency.

Breeding behaviour

Buffaloes continue to come in heat regularly in all months; highest being in October and lowest in April. No differences between months and seasons were observed with regard to per cent animals exhibiting oestrus and subsequent conception (Bhat *et al.* 1983). However, Tiwana *et al.* (1985) and Tailor *et al.* (1990) reported that around 75% of the total calvings took place during July to January (the most calving season) and only 25% during February to June (the least calving season) suggesting that buffaloes were seasonal breeder. These authors suggested that period of sexual activity in buffaloes appeared to be from September to December (74.8%). The sexual activity was very low between February and August (1.18 to 4.23%). This was because of non-detection of animals in silent heat by the farmers. Since suppression of oestrus is a part of climatological phenomena, it should be possible to modify it to some extent by adjustment in management and proper heat detection. Average number of services per conception ranged from 1.5 to 3.0. In general, heifers took more services than pluriparous buffaloes.

Age at first calving

A large variation in age at first calving across the breeds was noted; it being highest (54.6 months) in village buffaloes (Chhikara *et al.* 1978). The averages based on large numbers in Murrah and Nili-Ravi were between 40 and 44 months (Sreedharan and Nagarcenkar 1978, Reddy 1980). In Surti, and Bhadawari buffaloes, the age at first calving was slightly higher, 46-54 months (Vijai *et al.* 1993, Pundir *et al.* 1996). Pandharpuri buffaloes had an age at first calving between 38.4 and 39.8 months (Patil *et al.* 1994). Farm differences for age at first calving were significant (Johri and Bhat 1979 a, Dutt and Taneja 1994 b). These could be due to differential availability of inputs at the farms. The farm differences could also be genetic in nature due to differences in genetic merit of the sires used.

The heritability estimates for age at first calving varied between 0.12 and 0.53 (Gokhle 1974, Johri and Bhat 1979a, Basavaiah *et al.* 1983, Dutt and Taneja 1994b). Heritability estimates largely differed due to differences in number of sires used, progeny per sire and variation between individuals within halfsib groups apart from differences in genetic merit of sires used. Phenotypic and genetic correlations between age at first calving and first lactation milk yield were low or negative (El-Arain 1986, Dutt and Taneja 1994b). The negative genetic association between these 2 traits suggested that decrease in age at first calving would significantly increase milk yield.

Calving interval

The first calving interval in Murrah and Nili-Ravi buffaloes varied between 480 and 573 days and that the overall calving interval was lower (430-457 days) than the first calving interval (Lal 1975, Reddy and Taneja 1984, Dutt and Taneja 1995). In Bhadawari buffaloes it was 525 $\pm$ 25.9 days (Pundir *et al.* 1996). Average calving interval was 462$\pm$8 days in Surti buffaloes. The calving interval was maximum for first calvers and declined thereafter up to sixth parity (Jain and Tailor 1994).

Most of the heritability estimates reported for this trait were low and nonsignificant (El-Arain 1986, Dutt and Taneja 1995). The phenotypic correlations between first calving interval and first lactation milk yield were between 0.20 and 0.38 (Basu *et al.* 1978, Dutt and Taneja 1995). Longer calving intervals are associated with higher lactation yield. Such a phenotypic association was expected since prolonged calving intervals were the result of long lactation period probably due to late conception which was directly related to feeding, management and heat detection practices.

PRODUCTION

Part and total lactation yield

Part lactation records are used to predict the lactation milk yield and are also useful in early evaluation of sires. Various workers used 4 methods of extending part lactation records. These are (i) ratio, (ii) multiple regression, (iii) modified regression, and (iv) regression of remainder of lactation on the last test. Errors of multiple regression and regression estimates on the last test are minimum, modified regression intermediate while error of the ratio estimate was the largest. Around 12% of the total milk was produced in second month of lactation while around 30% of total milk was produced in first 90 days of lactation. The heritability of monthly milk production increased with stage of lactation up to sixth month and declined thereafter. Similarly, the genetic correlations among early months of lactation were higher than those among the later months. The genetic correlations between monthly and cumulative part and total yields showed a steady increase with each added month of lactation (0.90 - 0.99). In view of the higher heritability estimates of early segments of lactation curve and their high genetic correlation with total yield, selection on the basis of first 4 months cumulative yield or fourth to fifth monthly part yield would be as effective as that based on total yield (Kumar *et al.* 1978, Khan and Iqbal 1996).

Lactation curve

Various mathematical models, viz. exponential, parabolic exponential, gamma type and inverse polynomial were developed to explain the shape of lactation curve. Gamma function gave the best fit followed by inverse polynomial. Parity had significant effect on the initial milk yield in gamma function and year of calving affected significantly the average slope and average rate of decline of the lactation curve (Kumar and Bhat 1979, Vig *et al.* 1985).

Lactation milk yield

The average first lactation milk yield in Murrah buffaloes varied between 1 540 and 1 867 kg (Gokhle 1974, Johri and Bhat 1979 c, Gupta 1988, Khatkar *et al.* 1996) while in Nili-Ravi, it was 1 707 kg (Reddy and Taneja 1984). The first lactation averages for Bhadawari, Nagpuri and Marathwada were between 693 and 926 kg (Belorkar *et al.* 1977, Singh and Singh 1977, Sharma and Singh 1978, Pundir *et al.* 1996). Pandharpuri buffaloes gave a first lactation yield of 1 375 and 1 266 kg respectively in urban and rural areas (Patil *et al.* 1994). McDowell *et al.* (1995) compared performance details of Nili-Ravi breed of Pakistan, Murrah of India and Egyptian buffaloes and reported that 38% of all lactations in Nili-Ravi had more than 2 700 kg of milk as against 14% of all lactations in Murrah and 6% in Egyptian buffaloes.

Milk yield increased over the lactations with peak in fourth lactation (Patro and Bhat 1979, Tailor *et al.* 1992). More than 50% of the buffaloes left the herd by the end of fourth lactation and between 1 and 3% completed 10 lactations. Percentage of lactations terminated due to health, reproductive problems and death were around 30% each in lactation 1 and 2 (Cady *et al.* 1993).

Most of the heritability estimates for first lactation milk yield in Murrah and Nili-Ravi buffaloes were between 0.08 $\pm$ 0.04 and 0.19 $\pm$ 0.08 (Johri and Bhat 1979c, Pandey 1983, Sharma and Basu 1986, El-Arian 1986). Khan *et al.* (1996) reported the heritability estimate for first lactation milk yield in Nili-Ravi buffaloes as 0.14 $\pm$ 0.08 (intrasire regression of daughter on dam) and 0.27 $\pm$ 0.07 for milk yield expressed as most probable producing ability.

Measures of milk production efficiency

The first lactation milk yield is the most commonly used selection criterion in dairy animals. The eocnomic merit of dairy animals, however, is also influenced by parameters like age and weight at first calving, lactation length and calving interval. Some simple measures of milk production efficiency taking into account the variation caused by these factors need to be developed which has high genetic correlation with milk yield as reflected by higher heritability than that of milk yield. Some measures of milk production efficiency developed and studied are: milk yield/ day of age and weight at first calving, milk yield/ day of lactation length and per day of calving interval.

The average milk per day of first lactation length in Murrah buffaloes ranged between 5.30 and 5.68 kg (Bhalaru and Dhillon 1978, Reddy 1980, Dutt and Taneja 1994b), while in Nili-Ravi it was 6.04 kg (Singh and Singh 1977). The averages milk yield/ day of first lactation length for Bhadawari buffaloes was between 2.45 and 3.59 kg (Pundir *et al.* 1996, Singh and Singh 1997). The milk yield per day of lactation length in Surti buffaloes was 5.17 kg (Singh and Singh 1977). The average milk yield per day of first calving interval varied between 3.09 and 3.51 kg in Murrah (Bhalaru and Dhillon 1978, Umrikar and Desh Pande 1985, Dutt and Taneja 1994b), while in Bhadawari it was 1.52 kg (Pundir *et al.* 1996).

Bhalaru and Dhillon (1978), Reddy (1980), Bhat *et al.* (1982) and Dutt and Taneja (1994b) estimated genetic parameters for some measures of milk production efficiency and compared these with heritability estimates for milk yield. Most of the estimates reported by Reddy (1980) and Bhat *et al.* (1982) for milk production efficiency parameters were low. On the other hand, Bhalaru and Dhillon (1978) and Dutt and Taneja (1994b) observed that heritability estimates of milk yield per day of first lactation length (0.29 $\pm$ 0.10, 0.33 $\pm$ 0.08) were higher than that of first lactation yield (0.19 $\pm$ 0.09 , 0.23 $\pm$ 0.07). The genetic correlation between these 2 traits was more than 0.9. In view of higher heritability of milk yield/ day of first lactation length and higher genetic relationship with milk yield, selection on the basis of this trait would result in higher genetic improvement than expected from selection for milk yield. Heritability estimate for milk yield / day of age at second calving (0.31 $\pm$ 0.10) though reported to be higher and had high genetic correlation (0.83 $\pm$ 0.08) with first lactation yield (Bhalaru and Dhillon 1978), selection based on milk yield /day of age at second calving would increase the generation interval and thus lower genetic gain per unit of time.

Number of lactations completed and lifetime milk yield

Although, Nili-Ravi and Murrah breeds on an average completed 3 lactations, some studies reported the average number of lactations completed in Murrah to vary from 4.4 to 5.8 with lifetime yield 8 914 - 9 994 kg (Sharma and Basi 1986, Dutt and Taneja 1994a) and 4.5 to 5.6 lactations in Nili-Ravi buffaloes (Cady *et al.* 1983). The average number of lactations completed and lifetime milk yield in Surti were 3.72, 4 960 kg respectively (Kulkarni 1995).

Lifetime milk production (based on 3 lactations) ranged between 4 498.0 $\pm$ 26.2 and 5 251.1 $\pm$ 29.6 kg (Johri and Bhat 1979c, Gokhle and Nagarcenkar 1980, Singh and Yadav 1987) for Murrah buffaloes.

The heritability estimates for various lifetime parameters and measures of efficiency of lifetime traits varied between 0.07 and 0.30 (Kalsi and Dhillon 1984, Umrikar and Deshpande 1985, Singh and Yadav 1987, Dutt and Taneja 1994a) and were not substantially higher than those for first lactation yield to be used in the selection programme.

Examination of expected correlated responses in lifetime milk yield from selection for a single trait or indices based on first lactation traits revealed that the correlated response in lifetime milk yield was more than the direct response when selection was based on milk yield/day of first lactation length (Dutt and Taneja 1996). These results suggested that there was no advantage in basing selection on combining various early economic traits and that milk yield/day of first lactation length was an ideal trait for selection to achieve maximum genetic gain in lifetime milk yield.

MILK COMPOSITION

Buffalo milk has comparatively more fat and solid-not-fat (SNF) than cow milk. Monthly fat percentages were significantly influenced by stage of lactation. Fat percentage shared a continuous increase from first to tenth month. Differences in fat percentage between breeds also exist, the fat content being 12.6% in Chinese and 9.0% in Philippine buffaloes. Murrah breed has higher fat content than Nili-Ravi buffaloes. Large breed differences for fat per cent were also due to yield level, stage of lactation and type of feeding. The mean fat and SNF percentages in composite Murrah buffalo milk were 7.0 ± 0.04 and 10.1 ± 0.03 with a variation of 10 and 4.9% respectively (Singh *et al.* 1979). The means of fat and SNF percentage in Bhadawari buffaloes were 7.53 ± 0.94 and 9.55 ± 0.35 respectively (Pundir *et al.* 1996). Protein, lactose and minerals together constituted 9.6%. Per cent protein was highly heritable (0.74) while per cent ash (0.29), per cent total solids (0.35) and per cent solids-not-fat (0.39) were moderately heritable (Pal *et al.* 1971). The heritability estimates for per cent fat and SNF were 0.41 ± 0.28 and 0.26 ± 0.23 and the repeatability estimates for per cent monthly fat ranged from 0.20 to 0.48 and per cent SNF from 0.19 to 0.37 (Singh *et al.* 1979). Correlations between milk yield and milk constituent percentages were negative and ranged between 0.20 and 0.77. Genetic correlations among milk constituents however were positive (0.3 and 1.0). These results suggested that selection for milk yield would lower milk constituents percentages and vice-versa. Although, the increase in milk yield will decrease the milk constituents percentages, the total fat, protein and SNF yield would increase as all yields are positively correlated with milk yield.

SELECTION INDEX

Selection index estimates the value of an individual for an aggregate genotype and is a linear combination of additive genetic merit for component traits weighted by their respective economic weights. Examination of various indices revealed that first lactation milk yield was the most important trait (Sharma and Basu 1986, Dutt and Taneja 1994) and addition of age at first calving, first calving interval and other early economic traits improved the net genetic gain in the aggregate genotypic value of the index to some extent. Most selection studies recommended an index combining age at first calving, first lactation 305-day milk yield and first lactation length as ideal one for buffaloes. The efficiency of the selection increased further when both age and weight at first calving were combined alongwith part lactation milk yield in selection indices (Gokhle and Nagarcenkar 1980).

RESULTS OF SELECTION SCHEMES

Annual genetic gains in milk yield were estimated for herds kept under selection for milk yield. The annual genetic gain in 300-day first lactation milk yield in Murrah and Murrah grades at military farms of 15.88 kg which was equal to 0.99% of the herd average of 1 611.26 kg was reported by Reddy and Taneja (1982). The genetic gain amounting to 3.28 kg of milk or 0.17% of the average first lactation milk yield (1 879 ± 39 kg) was estimated by Khan (1994). The estimates of annual phenotypic trend in buffalo herd at the PAU, Ludhiana, revealed that both age at first calving and milk yield showed an increase and lactation period a decrease over the years. The annual rate of genetic progress in first lactation milk yield was estimated as 4.5 kg. This was about 0.27% of the herd average. The genetic decline was 0.94 months in age at first calving per year whereas first lactation period increased by 1.2 days/ year (Tiwana *et al.* 1985). Amongst the several factors responsible for relatively low genetic gains for milk yield may be the subjective basis of selection, less genetic variability, low culling rates etc.

For achieving higher genetic gains, the only alternative is to initiate and strengthen progeny testing programmes for important breeds. Progeny testing programmes for Murrah, Surti, and Mehsana were in existence and evaluation of bulls is being done using appropriate sire evaluation methodologies. Progeny testing programmes for Murrah and Mehsana have large field base involving farmers animals and envisage producing 100 completed first lactation records of progenies per bull. Milk production and fat percentage of each daughter are measured once a month till it completes lactation. The best linear unbiased estimates of the top 10 sires (28 to 90 daughters) ranged between + 67.1 and + 152.7. The overall sample average first lactation yield of daughters was 1 917 ± 38 kg and age at first calving was 42.9 ± 8.1 months (Trivedi 1997).

Bulls/semen produced in buffaloes is of indifferent quality. The approach, therefore has to be of producing large number of quality males through nominated matings and screen them for accurate information on their breeding value and use the best ones for achieving higher genetic gains. The only option is to develop/strengthen the field recording programmes with farmers participation on co-operative basis for important buffalo breeds having buffalo population of around 10 000. All buffaloes in the programme should be identified, registered and a system of performance recording developed. Inputs like health care, artificial breeding, feeds and fodders and marketing should be built into this system. Farms should be established for rearing of young males. Sequential selection among males should be following growth rate, production records of dams and semen test. The bulls finally clearing the semen test should be used in test mating and those with higher breeding value used for breeding. Such programmes of progeny testing should be linked and coordinated at national level. Research inputs for improving AI and semen quality in buffaloes and methodologies for sire evaluation under field conditions should be made available.

Field base for some breeds like Bhadawari and Surti is shrinking because of their low milk production potential and crossing with Murrah. It is essential that these breeds are improved in their native tracts with farmers' participation so as to build a reasonable population size for effecting genetic improvement.

A maximum genetic gain of 1 to 1.5% in milk yield using intense selection of bulls under progeny testing is possible. Multiple ovulation and embryo transfer techniques offer a great potential to increase slection response for milk yield in buffaloes. There is a large genetic diversity available in buffalo breeds; crossing between them needs to be attempted to combine desirable genes of Murrah for high milk and medium fat; of Bhadawari for greater heat tolerance and high fat and Surti for regularity of breeding.

No definite breeding programmes for raising river breeds for meat production exist. It would be desirable to cross buffaloes with less than average milk yield with buffalo bulls selected on the basis of faster rate of gain and higher feed efficiency for production of calves to be raised for meat.

REFERENCES

Basavaiah P, Siddappa L, Kulkarni V S and Mukundkrishana A. 1983. Study on genetic parameters of the first lactation in Surti buffaloes, Dharwad. Sixth Workshop on AICRP on Buffalo. Report of Dharwad Centre, pp.33-35.

Basu S B and Rao M K. 1979. Growth pattern in Murrah buffalo calves. *Indian Veterinary Journal* **56**: 570-74.

Basu S B, Sharma P A and Nagarcenkar R. 1978. Gestation period and birth weight in Murrah buffaloes. *Indian Journal of Dairy Science* **3**:294-96.

Basu S B, Tomar O S and Ghai A S. 1984. Genetic studies on sexual maturity traits of buffalo heifers. *Indian Journal of Animal Sciences* **54**: 14-18.

Belorkar R M, Khire D, Kadu M S and Kaikini A S. 1977. Studies on the effect of service period on lactational yield, lactational period and dry period in Nagpuri (Berari) buffaloes. *Indian veterinary Journal* **54**: 384-88.

Bhalaru S S and Dhillon J S. 1978. Estimate of phenotypic and genetic parameters of some measures of efficiency of milk production in buffaloes. *Journal of Agriculture Science (Cambridge)* **91**:181-83.

Bhat P N, Koul G C and Kumar R. 1982. Note on factors affecting various milk yield efficiency traits in buffaloes. *Indian Journal of Animal Sciences* **52**: 936-38.

Bhat P N, Kumar R and Raheja K L. 1983. Breeding behavior of Murrah buffaloes. Proceedings of Fourth International Congress of SABRAO, pp. 91-97.

Bhat P N and Taneja V K. 1987. Genetics and Breeding of River Buffalo. IVRI Research Bulletin. No. 5, pp. 1-62.

Cady R A, Shah S K, Schermerhorn E C. and Mc Dowell, R.E. 1983. Factors affecting performance of Nili-Ravi buffaloes in Pakistan. *Journal of Dairy Science* **66**: 578- 86.

Chhikara B S, Balaine D S, Chaudhary S R and Chopra S C. 1978. Performance levels and culling patterns in Murrah buffaloes. *Indian Journal of Dairy Sciences* **31** : 292-93.

Dutt T and Taneja V K. 1994a. Estimates of phenotypic and genetic parameters of lifetime performance traits in Murrah buffaloes. *Indian Journal of Animal Sciences* **64** : 384-87.

Dutt T and Taneja V K. 1994b. Phenotypic and genetic parameters of age at first calving, first lactation milk yield and some measures of efficiency of production in Murrah buffaloes. *Indian Journal of Animal Sciences* 64 : 966-68.

Dutt T and Taneja V K. 1995. Genetic studies on first lactation length, first dry period and first calving interval in Murrah buffaloes. *Indian Journal of Animal Sciences* **65**:339-40.

Dutt T and Taneja V K. 1996. Genetic improvement in life-time milk yield expected form selection on single traits or indices. *Indian Journal of Animal Sciences* **66**:371-74.

El-Arian M N and Tripathi V N. 1990. Selection of Murrah buffaloes for net economic merit. *Indian Journal of Dairy Science* **43**: 540-43.

Gokhale S B. 1974. 'Inheritance of part lactations and their use in selection among Murrah buffaloes.' Ph.D. Thesis. Agra University, Agra.

Gokhale S B and Nagaracenkar R. 1980 . The selection indices based on part lactation of Murrah buffaloes. *Indian Journal of Heredity* **12**:57-66.

Gupta B D. 1988. 'Genetic and nongenetic factors affecting components of reproductive efficiency and their relationship with milk production in buffaloes.' Ph.D. Thesis, Rohilkhand University, Bareilly.

Jain L S and Tailor S R. 1994. Inheritance of reproduction traits in Surti buffaloes. *Indian Veterinary Journal* **71**:684-88.

Johari D C and Bhat P N. 1979a. Effect of genetic and non-genetic factors on reproductive traits in Indian buffaloes. *Indian Journal of Animal Sciences* **49**:1-6.

Johari D C and Bhat P N. 1979b. Effect of genetic and non-genetic factors on body weight in buffaloes. *Indian Journal of Animal Sciences* **49**:597-603.

Johri D C and Bhat P N. 1979c. Effect of genetic and non-genetic factors on production traits in buffaloes. *Indian Journal of Animal Sciences* **49**:984-91.

Kalsi J S and Dhillon J S. 1984. Estimates of phenotypic and genetic parameters of some measures of life-time production in buffaloes. *Indian Journal of Dairy Science* **37**:269-71.

Khan M A. 1994. Buffalo selection schemes in Pakistan. *Proceedings of the first ABA congress*, pp. 96-105, Khon kaen.

Khan M P and Iqbal J. 1996. Recent developments in buffalo breeding research in Pakistan. *Proceedings of the 2nd Asian Buffalo Association Congress*, pp. 54-62. Manila, Phillippines.

Khan M A, Mohiuddin G and Javed K. 1996. Inheritance of some performance traits in Nili-Ravi buffaloes. *Proceeding of the 2nd Asian Buffalo Association Congress*, pp. 334-38. Manila, Phillippines.

Khatkar, M.S, Sethi, R.K. and Tripathi, V.N. 1996. Repeatability of economic traits in Murrah buffaloes. Proceedings of the 2nd Asian Buffalo Association Congress, pp. 346-48. Manila, Philipplines.

Kulkarni V S. 1995. ' Genetic evaluation of Surti buffaloes.' Ph.D. Thesis Kurukshetra University, Kurukeshtra.

Kumar D O, Sharma P and Manglik V P. 1990. Genetic studies on cumulative part lactation yield in Indian buffaloes. *Indian Journal of Animal Sciences* **60**: 338- 41.

Kumar R, Bhat P N and Garg R C. 1978. Inheritance of various segments of lactation curve in Indian buffaloes. *Indian Journal of Animal Sciences* **48**:652-55.

Kumar R and Bhat P N. 1979. Lactation curve in Indian buffaloes. *Indian Journal of Dairy Science* **32** : 156-60.

Lall H K. 1975.Study of economic characters in Murrah buffaloes. *Indian Veterinary Journal* **52**: 337-44.

Marwaha C L. 1974. 'Genetic, phenotypic and environmental relationships between body weights at different ages and milk production in buffaloes.' M.Sc. Thesis, Punjab Agricultural University, Ludhiana.

McDowall R E, Wilk J C, Shah S K, Balain D S and Melry G H. 1995. Potential of commercial dairying with buffalo. North Carolina State University, USA.

Misra B S, Raizada B C and Tewari R B L.1970. Gestation length, birth weight of calves and body weight changes during pregnancy in buffaloes bred during summer. Indian Journal of Animal Sciences **40**:103-109.

Murdia C K and Chaudhry A L. 1984. Genetic studies on body weights in light breeds of buffaloes. *Indian Journal of Animal Sciences* **54**(10):6-10.

Nautiyal L P and Bhat P N. 1979. Effect of various factors on body weights in Indian buffaloes. *Indian Journal of Animal Sciences* **49**:979-83.

Pal S, Basu S B and Sengar O P S. 1971. Heritabilities and genetic correlations for milk constituents in Murrah buffaloes. *Indian Journal of Animal Sciences* **41**: 1019-21.

Pandey R S. 1983. 'Genetic studies on age and weight at first calving, milk yield and other production efficiency traits in buffaloes.' M.Sc. Thesis. G.B. Pant University of Agriculture and Technology, Pantnagar, UP.

Patil S S, Mali S L, Patil P R and Patil B R. 1994. Preliminary studies on productive and reproductive performance of Pandharpuri buffaloes maintained under rural and urban conditions. Proceedings of the first ABA congress, pp. 135-37. Khon kaen.

Patro B N and Bhat P N. 1979. Effect of some non-genetic factors on production traits in Indian buffaloes. *Indian Journal of Animal Sciences* **49**:91-98.

Pundir R K, Vij R K, Singh R B and Nivsarkar A E.1996. Bhadawari buffaloes in India. Animal Genetic Resources Information, 17, FAO, Rome, Itly. pp. 109-22.

Reddy C E. 1980. 'Genetic analysis of breeding records of buffaloes.' Ph.D. Thesis, Kurukshetra University, Kurukshetra.

Reddy C E and Taneja V K. 1982. Genetic trends for 300 days first lactation milk yield in Murrah buffaloes. *Second World Congress on Genetics Applied to Livestock Production*, pp. 152-56, Madrid.

Reddy C E and Taneja V K.1984. Factors influencing the first lactation traits of Nili-Ravi buffaloes. *Indian Journal of Dairy Science* **37**:36-39.

Sharma A and Basu S B. 1984. Genetic architecture of Nili buffaloes. 1. Growth. *Indian Veterinary Journal* **61**:227-32.

Sharma A and Basu S B. 1986. Optimization of breeding and managemental variables for maximizing lifetime milk production and profit in Murrah buffaloes.*Indian Journal of Animal Sciences* **56**:64-71.

Sharma R C and Singh B P. 1978. Evaluation of the genetic potential of Bhadawari buffaloes. 2. Reproductive characters. *Indian Veterinary Journal* **55**:751-55.

Singh C V and Yadav M C. 1987. A genetic study on part lactation production in Indian buffaloes. *Indian Journal of Animal Sciences* **57**: 154-57.

Singh H P and Singh R. 1977. Statistical studies of some economic traits of Indian buffaloes. *Indian Veterinary Journal* **54**:823-33.

Singh A, Basu S B and Bhatia K L.1979. Milk, fat and SNF percentages of Murrah buffaloes. *Indian Journal of Dairy Science* **32**: 446-49.

Sreedharan S and Nagarcenkar R. 1978. *Relation of Body Size Measures to Production Efficiency in Murrah Buffaloes*. pp. 5. Brief Communication, 20th International Dairy Congress, Paris.

Tailor S P, Jain L S, Gupta H K and Bhatia J S. 1990. Oestrus and conception rates in buffaloes under village conditions. *Indian Journal of Animal Sciences* **60**:1020-21.

Tailor S P, Jain L S and Kothari M S. 1990. Effect of weight at first calving on lactational performance in buffaloes. *Livestock Advisor* **15**(7):15-16.

Tailor S P, Jain L S and Tusavara M. 1992. Analysis of milk yield, lactation length, and dry period in Surti buffaloes. *Indian Journal of Animal Sciences* **62**:479-81.

Tiwana M S, Arora B S, Bhullar M S, Singh N, Sindhu S S and Singh J. 1985. Buffalo breeding at PAU Ludhina- A profile. *SARAS Livestock and Poultry Production* **1**:48-54.

Trivedi K R. 1997. Dairy herd improvement programme actions. *Buffalo Newsletter* 7:4-6.

Umrikar U D and Deshpande K S. 1985. Genetic studies on lactation length and dry period in Murrah buffaloes. *Indian Journal of Animal Sciences* **55**:888-92.

Vij P K, Tiwana M S and Bhullar M S. 1985. Factors affecting shape of lactation course in buffaloes. *Asian Journal of Dairy Research* **4**(2): 111- 15.

Vijai R G, Jain L S and Tailor S P. 1993. Body weights and their genetic and phenotypic parameters in Surti and Mehsana buffaloes. *Indian Journal of Animal Sciences* **63**:152-55.