# EFFECT OF CALVING SEASON AND CLIMATIC FACTORS ON AGE AT PUBERTY, SERVICE PERIOD AND SUCCESSFUL MATING IN NILI-RAVI BUFFALO

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## ABSTRACT

A retrospective analysis was conducted to examine the effect of season and climatic factors on age at puberty, service period and successful mating of Nili-Ravi buffalo maintained at a Public Sector Dairy Farm in Okara, Pakistan. Records, spread over a period of 13 years (2000 to 2012), for 583 buffaloes were analyzed for this purpose. Age at puberty was calculated by subtracting date of birth from date of first fruitful service. Average age at puberty and service period were 1056.87±83.11 and 193.81±47.32 days respectively. Season of birth had a significant effect (P<0.05) on age at puberty. Calves born in winter had a shorter age at puberty (962.09±9.81) compared with those born in other three seasons (spring, summer and autumn). Effect of calving season on service period was significant (P<0.05). Autumn calvers had the shortest service period (193.81±47.32). Service period did not differ with calving year (P>0.05). Month of the year and successful mating (r = 0.67) were positively correlated with each other (P<0.05). Maximum and minimum number of successful mating were recorded in October (21.75%) and June (3.88%). The correlation between individual climatic factors (i.e. daily temperature, rain fall, sunshine hours, relative humidity) and successful mating was non-significant (P>0.05). It was concluded that climatic factors did affect the reproductive activities but their individual effect was non- significant in buffalo. However, season, a combination of climatic factors, had significant effect on reproductive activities.

**Keywords**: *Bubalus bubalis*, buffaloes, climatic factor, season, service period, age at puberty

## INTRODUCTION

Buffalo is the second most important animal contributing 13% in global milk production. This versatile animal is mostly reared in developing or under developed countries and thorough exploration to exploit its full potential is in progress. In India and Pakistan 65 to 70% percent of total milk is derived from buffaloes. The productive and reproductive efficiency of animals are complementary to each other. Low reproductive efficiency of livestock in general and particular in buffalo remains a major economic problem globally (Nanda *et al*., 2003). High age of puberty and prolonged calving interval are important problems with buffalo (Bhatti *et al*., 2007; El-Wishy, 2007). Understanding of factors affecting reproductive

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efficiency will be helpful to augment reproductive performance of buffalo. Among these, the effect of climatic factors on their reproductive performance must be critically investigated. The present study was planned with the objective to analyze the effect of climatic factors and season on different fertility parameters retrospectively in Nili-Ravi buffalo, one of the best milk buffalo breeds in the world.

## MATERIALS AND METHODS

Retrospective analysis of data, recorded in a public sector buffalo farm, was performed. The buffalo farm is located at Okara (Pakistan) with a latitude 30.8000° N, longitude 73.4500° E and 180 meters above sea level. More than 1000 buffalo are being maintained at this farm since many years. Animals were kept loose (untied) in semi open sheds. Seasonal green fodder (25 to 30 kg), concentrate (5 to 9 kg) along with wheat straw (10 to 20 kg) was offered per animal per day. Mineral blocks were placed in mangers for licking. The animals had free access to clean drinking water round the clock. Anthelmentics were used quarterly. Vaccination for Foot and Mouth Disease, Black quarter and Hemorrhagic septicemia was done once a year. Buffalo were hand milked twice daily; calves were allowed limited suckling at the time of milking for milk let down. Each herd of fifty to ninety buffalo was kept with an intact bull round the clock for natural mating. Animals served were recorded by the attendants.

### Parameters analyzed

Production and reproduction record of 663 buffaloes over thirteen years (2000 to 2012) were analyzed to assess reproduction performance of buffalo at the farm and correlate it with season and climatic factors. Following information were collected for this purpose.

- Season and month of breeding
- Season and month of calving
- Service period i.e. days from calving to fruitful service
- Calving interval

Age at puberty (i.e. the age at first fruitful service)

Data regarding the climatic factors i.e. daily temperature, rain fall (RF), sunshine hours (SSH) and relative humidity (RH) (from 2000 to 2012) for Okara was obtained from Metrology Department. Monthly averages and standard error for these factors were calculated. The year was split into following 4 seasons (Naqvi, 2000).

- Winter season: November, December, January
- Spring season: February, March, April
- Summer season: May, June, July
- Autumn season: August, September, October

### Statistical analysis

Monthly means of the climatic factors for temperature, rain fall (RF), relative humidity (RH), sunshine hours (SSH) at Okara during 2000 to 2012 were calculated. Analysis of variance and Tukey's test was applied to compare means along with Pearson's correlation analysis. Frequency of animals breeding/calving in various seasons was compared by chi-square statistics. A P-value <0.05 was used to define statistical significance. Analysis was performed using the Minitab (version 17) statistical package.

## RESULTS AND DISCUSSION

### General reproduction traits

Data were utilized for 663 buffaloes with calving records from 2000 to 2012. After excluding abortions and stillbirths, record of 583 buffaloes was available with 1,387 normal calving. The age at puberty and service period characteristics of these buffaloes at Dairy Farm are presented in Table 1.

The age of puberty in buffalo heifers was recorded as 1,056.87±83.11 days (35.2 months). Average age at puberty in buffalo heifers has been reported 37 months in Pakistan (Bashir, 2006) and 33 months in Murrah buffalo (Haldar and Prakash, 2006). The age at puberty in the present study was thus comparable with above two reports. Younger age at puberty is highly desired trait for the livestock and is the result of a dynamic interaction between environmental cues (nutrition, management and climate) and genetic factors. There is indication that the endocrine activity is related to body weight of female (Rawlings *et al*., 2003) so attempts have been made to decrease age at puberty in buffalo and cows by concentrate feeding (Khanum *et al*., 2012) Stair-step feeding (Park *et al*., 1998; Anjam *et al*., 2011) and hormones (Haldar and Prakash, 2005). However their impacts on life time productivity of animals has not been studied, and these nutritional recommendations to lower the age at puberty in buffalo have not been adopted by livestock farmers. Due to complex dependency of age at puberty on genetic and environmental factors, the long term solution lies probably in selective breeding (heritability of 0.21 in Nili-Ravi buffalo; Suhail *et al*., 2009), saving from heat stress and by focusing on nutrition and health care from weaning to adult hood which means age at puberty can be decreased by individual selection of animal. Most of cattle and buffalo heifers in Pakistan are being reared conventionally on poor quality roughages, resulting in slow growth rates (Jabbar *et al*., 2006).

Service period, the interval from calving to conception is of great economic importance as a longer service period increases the calving interval, resulting in a reduced productive life time and increased cost of milk production. Service period in the present study was 193.81±47.32 days and it is lower than that described by Naqvi, (2000); Hussain *et al*. (2006) 237±4.5 and 208.35±24.03 days, respectively.

A short service period is desired to maintain the calving interval of 365 days but it is not achieved in buffalo due to many reasons (poor estrous expression, nutrition etc). Inconsistent effects of parity and season of calving and suckling on service period have been reported (Shafiq and Usmani, 1996). The incorporation of service period in the indices for the genetic improvement of buffalo reflects its importance (Chakravarty *et al*., 1991).

#### Effect of season of birth on age at puberty

The effect of season of birth was significant (P<0.05) on the age at puberty of Nili-Ravi heifers (Table 2). Animals born in winter had a shorter age at puberty compared with those calving in other seasons. Puberty is linked both with age and body weight (Bhatti *et al*., 2007; Khanum *et al*., 2012; Terzano, 2012). Average age at puberty in all the calves born in four seasons in the present study was above 960 days. It seems that heifers gained body condition and live weight critical to achieve puberty soon after an average age of 900 days under the feeding and management prevailing in present study. As buffaloes are reported as short day breeders and have a well documented peak breeding season (Perera, 2011) calves born in winter will come across this period soon after 900 days of age and will start ovulatory cycle. In contrast, the animals born in summer and autumn will attain this situation during long days, thus puberty will be delayed in them until next peak breeding season. This phenomenon has also been recorded in sheep, another short day breeder (Papachristoforou *et al*., 2000). The dark and light sensitive phases of biological clock are well established and play a key role in altering the reproductive status (seasonal breeding). It has been suggested that the seasonal reproductive activity may have robust mechanism controlled by the master body clock (Matthews *et al*., 1993).

**Effect of season on service period**

Calving season had a significant effect on service period of Nili-Ravi Buffaloes maintained at Dairy farm, Okara during 2000 to 2012 (Table 3). This observation is in line with earlier reports in Nili-Ravi (Thevamanoharan, 2002) and Murrah buffaloes (Chhikara *et al*., 1995). There is indication that geographical location may have a modulating effect, as Hussain *et al*. (2006) observed no effect of season on service period in Nili-Ravi buffalo maintained at Muzaffarabad. The interval from calving to clinically completed involution of the uterus in dairy buffaloes varied widely with a minimum of 15 days a maximum of 74 days. Shortest service period was observed in autumn calvers in the present study. It may be that after completion of uterine involution, autumn calvers buffaloes meet short days and get served. Buffaloes calved in Spring have longest service period (Naqvi, 2000) which seems quite logical as after calving and uterine involution, the succeeding months are June and July, the long days with high ambient temperature. Animal showed anoestrus and ovarian cyclicity restarted in by the end of September (after 210 days or 7 months) and it was also true for summer calvers.

**Effect of calving year on service period**

A non-significant (P>0.05) effect of calving year on service period was observed during the present study that might be due to a uniform farm management and climate/season over this duration. A non-significant (P>0.05) effect of calving year on service period was observed during the study. Similar observations were also incorporated in Nili-Ravi and Murrah buffaloes (Ali *et al*., 2011; Saha *et al*., 2000). A probable reason of non-significant response is this that the farm management and climate/season remained same over this duration and no change in procedures of herd management had occurred. However, some studies revealed significant effect (P<0.01) of years of calving on service period of buffaloes (Singh and Nivasarkar, 2000). The reason for the difference is may be the variation of season and farm management as the first study was conducted in Barani areas of Punjab and most probable the variation in rain fall in arid area and fodder provided to animals were the responsible factors.

**Effect of month of the year on breeding, calving activity and relationship with climatic factors**

Relationship of breeding and calving pattern of buffaloes with climatic factors i.e. (temperature, rainfall, relative humidity, and sun shine hours) is depicted in Table 4. Correlation between various monthly climatic factors and fruitful services is shown in Table 5.

Month wise breeding and calving pattern in Nili-Ravi buffaloes during 2000 to 2012 at dairy farm, Okara is depicted in Table 5. Highest number of buffaloes conceived in October (21.75%) and lowest in June (3.88%). Consequently maximum and minimum number of calvings were observed in the month of August (18.17%) and February (3.25%). Seasonal influence on estrus incidence and conception rate has been reported in Nili-Ravi buffaloes in many other studies (Terzano et *al*., 2012) indicating reproductive cyclicity during decreasing day light. Similar observations have been recorded on other breeds of buffaloes from Italy and India. Zicarelli *et al*. (1997) observed that the resumption of the reproductive cycle in Italian buffalo took place from September (light decreasing period) until January (increasing light period predominantly dark hours). It was further reported that this phenomenon had been observed both with free grazing herds as with stabled herds. Seasonal effects on breeding efficiency in Murrah buffalo was also reported (Agarwal, 2003).

Although, breeding and calving occurred throughout the year, maximum number of fruitful services (21.75%) was recorded during the month of October followed by that in September (14.43%). Minimum number of fruitful services was recorded in June (3.88%) and May (4.32%). Although, a non-significant (P>0.05) effect of individual climatic factors was noted during the study period, a significantly positive correlation (r = 0.67) existed between the months of the year and fruitful services (P<0.05). A significant correlation of breeding with month depicted that all the climatic factors did have a cumulative impact on reproductive activity. Similarly significantly positive correlation (r = 0.53) existed between the months of the year and calving frequency (P<0.05). Although, Indian and Pakistan's reports attribute the decline of reproductive activity that was observed in summer to the heat stress (Qureshi, 2011) but it seems that in South Asian situation, seasonality in buffalo reproduction is not due to heat stress alone as we observe a decline in breeding with onset of January that is a cooler month and declines further in spring. Photo periodicity may be the major factor, and heat stress might just exaggerate the situation. The role of photoperiod was evident in the breeding pattern of buffalo in Italy where increased ovarian cyclic activity was observed with decreasing day-light hours (Campanile *et al*., 2010). It is evident from the above discussion that although buffalo is a polyestrous animal but shows distinct peak and low breeding seasons and a dominant role of sunshine hours that control "start and stop" of breeding in buffalo. The function of melatonin in the control of reproductive seasonality was quite well known in seasonal breeders such as sheep (Rosa and Bryant, 2003). Pineal gland secretes melatonin and the secretion pattern of hormone followed a circadian rhythm with high levels only during the dark periods (Parmeggiani *et al*., 1994). A similar observation regarding the melatonin production had been reported from Italian in Mediterranean buffaloes with significant concentrations in the period of shorter days (Parmeggiani *et al*., 1994; Borghese *et al*., 1995). Low concentration of melatonin in blood during the period of increasing day light had inhibitory effect on ovarian activity in buffalo (Parmeggiani *et al*., 1993; Zicarelli, 1997). Some buffaloes showed ovarian activity even in longer days indicated the opportunity of selective breeding and this was tried in Italy (Zicarelli, 1997). The calving pattern observed in the present study logically followed a seasonal trend ruled by conception season. Although calving occurred throughout the year, highest calving frequency was recorded in autumn (41%) and summer (30%) followed by winter (20.66%) and spring. These observations were in agreement with reports in Nili-Ravi (Ali *et al*., 2011) Kundi (Bughio *et al*., 2000) and Murrah buffaloes (Singh *et al*., 2000).

Table 1. Reproductive traits of Nili-Ravi buffaloes at buffalo farm Okara over 2000-2012.

| Production parameters | Number of records | Mean ± SEM | Range |
|---|---|---|---|
| Age at puberty (Days) | 583 | 1056.86±83.11 | 414-1287 |
| Service Period (Days) | 836 | 193.81±47.32 | 40-450 |

Table 2. Effect of season of birth on age at puberty in Nili-Ravi Buffalo at dairy farms Okara over 2000-2012.

| Season of birth | Number of records | Age of puberty (days) mean ± SEM |
|---|---|---|
| Winter* | 224 | 962.09±9.81[a] |
| Spring** | 28 | 1074.6±13.35[b] |
| Summer*** | 72 | 1109.8±10.53[c] |
| Autumn**** | 252 | 1081.0±6.52[b] |

Means with different superscripts differ significantly (P<0.05).
*Winter (November, December and January)
**Spring (February, March and April)
***Summer (May, June and July)
****Autumn (August, September and October)

Table 3. Effect of calving season on service period (days) of Nili-Ravi buffaloes maintained at dairy farm, Okara during 2000-2012.

| Calving season | Number of records | Service period (days) (means ± SE) |
|---|---|---|
| *Winter | 203 | 188.33±20.20[a] |
| **Spring | 138 | 214.62±12.29[b] |
| ***Summer | 173 | 196.23±12.31[ab] |
| ****Autumn | 320 | 176.48±12.37[a] |

Means with different superscripts differ significantly (P<0.05).
*Winter (November, December and January)
**Spring (February, March and April)
***Summer (May, June and July)
****Autumn (August, September and October)

Table 4. Monthly breeding and calving frequencies of buffaloes along with temperature, relative humidity, sunshine hours and rain fall per month over years 2000 to 2012.

| Month of the year | No. of animals conceived & (%) | No. of animals calved & (%) | Max.Temp. (°C) mean ± SEM | Min.Temp (°C) mean ± SEM | Rain Fall (mm) mean ± SEM | Rel. Humidity (%) mean ± SEM | Sun Shine (hrs/day) mean ± SEM |
|---|---|---|---|---|---|---|---|
| January | 90 (6.49) | 62 (4.47) | 18.76±0.69 | 4.50±0.32 | 24.80±4.06 | 66.47±2.74 | 4.93±2.01 |
| February | 60 (5.33) | 53 (3.25) | 23.00±0.54 | 7.40±0.42 | 12.60±6.61 | 56.68±2.30 | 7.17±2.92 |
| March | 67 (5.83) | 70 (5.41) | 30.76±0.57 | 14.20±0.43 | 3.00±0.66 | 41.95±7.21 | 8.62±3.51 |
| April | 63 (5.31) | 60 (4.33) | 36.48±0.97 | 19.10±0.54 | 23.30±5.63 | 36.85±3.53 | 9.12±3.72 |
| May | 46 (4.32) | 75 (5.61) | 40.87±0.45 | 24.10±0.78 | 9.30±2.84 | 34.87±2.39 | 9.98±4.07 |
| June | 37 (3.88) | 100 (7.21) | 40.67±0.58 | 26.20±0.36 | 55.20±26.34 | 46.10±5.23 | 9.26±3.64 |
| July | 57 (5.11) | 163 (11.75) | 38.43±0.38 | 27.10±0.27 | 76.80±28.8 | 56.02±5.89 | 8.92±3.77 |
| August | 92 (6.63) | 252 (18.17) | 37.00±0.47 | 26.20±0.18 | 74.00±43.45 | 60.45±6.83 | 9.22±3.76 |
| September | 214 (14.43) | 195 (14.06) | 35.10±0.36 | 23.00±0.33 | 58.70±34.02 | 59.05±7.39 | 8.68±3.54 |
| October | 260 (21.75) | 155 (11.18) | 33.87±0.29 | 18.10±0.51 | 13.40±2.23 | 49.52±5.51 | 8.80±3.59 |
| November | 145 (11.45) | 116 (8.36) | 28.25±0.48 | 11.60±0.31 | 0.00±0 | 53.07±7.63 | 7.20±2.93 |
| December | 155 (10.18) | 86( 6.20) | 22.08±0.46 | 6.40±0.45 | 11.00±1.97 | 48.97±10.08 | 5.76±2.35 |

Table 5. Correlation between various monthly climatic factors and fruitful services.

| Climatic factors | r-value | P-value |
|---|---|---|
| Max monthly temperature | -0.03 | 0.91 |
| Average rain fall | -0.01 | 0.97 |
| Average humidity | 0.21 | 0.52 |
| Average sun shine hours | -0.07 | 0.81 |

## CONCLUSION

It was concluded that reproductive parameters like age at puberty and service period were under seasonal influences though body weight and nutrition were also contributing factors. Buffaloes had shown distinct breeding season with some animals cyclic round the year. The selection of animals with desired parameters like young age at puberty and short service period can improve the reproductive performance in buffalo with due attention to the management.

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## REFERENCES

Agarwal, P. 2003. Augmentation of reproduction in buffaloes. *In Proceedings of 4th Asian Buffalo Congress: Lead Papers*, New Delhi, India. 121p.

Ali, A., K. Javed, N. Ahmad and S.U. Rehman. Environmental factors affecting some reproductive traits in Nili-Ravi buffaloes. *J. Anim. Plant Sci*., **21**(4): 868-887.

Bashir, M.K. 2006. *Genetic and phenotypic aspects of some performance traits of Nili-Ravi buffaloes in Pakistan*. Ph.D. Thesis, University of Agriculture, Faisalabad, Pakistan.

Bhalla, R.C., B.K. Soni and D.P.S. Sengar. 1966. Studies on reproduction in Murrah buffaloes. Involution of uterus. *Indian Vet. J*., **43**(10): 892-896.

Bhatti, S.A., M. Sarwar, M.S. Khan and S.M.I. Husain. 2007. Reducing the age of first calving through nutritional manipulation in dairy buffaloes and cows. *Pak. Vet. J*., **27**(1): 42-47. Available on: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.530.4925&rep=rep1&type=pdf

Bughio, S., A.K. Shahani, A.H. Mirani, A. Moriani, F.C. Oad and B.A. Bughio. 2000. Seasonal trend of calving and subsequent service period in Buffaloes. *Pakistan Journal of Biological Science*, **3**(12): 2169-2170. DOI: 10.3923/pjbs.2000.2169.2170

Campanile, G., P.S. Baruselli, D. Vecchio, A. Prandi, G. Neglia, N.A.T. Carvalho, J.N.S. Sales, B. Gasparrini and M.J. D'Occhio 2010. Growth, metabolic status and ovarian function in buffalo (*Bubalus bubalis*) heifers fed low energy or high energy diet. *Anim. Reprod. Sci*., **122**(1-2): 74-81. DOI: 10.1016/j.anireprosci.2010.07.005

Chhikara, S.K., N. Singh, S.S. Dhaka and R.S. Yadav. 1995. Effect of certain factors on calving interval of Murrah buffaloes. *Journal of Dairying, Food Home Sciences*, **14**: 29-32.

El-Wishy, A.B. 2007a. The postpartum buffalo: Endocrinological changes and uterine involution. *Anim. Reprod. Sci*., **97**(3-4): 201-215. DOI: 10.1016/j.anireprosci.2006.03.004

Haldar, A. and B.S. Prakash. 2005. Peripheral patterns of growth hormone, luteinizing hormone, and progesterone before, at and after puberty in buffalo heifer. *Endocrine Research*, **31**(4): 295-306. DOI: 10.1080/07435800500422608

Haldar, A. and B.S. Prakash. 2006. Growth hormone-releasing factor (GRF) induced growth hormone advances puberty in female buffaloes. *Anim. Reprod. Sci*., **92**(3-4): 254-267. DOI: 10.1016/j.anireprosci.2005.06.002

Hussain, Z., K. Khalid, S.M.I. Hussainn and G.S. Kiyani. 2006. Reproductive performance of *Nili-Ravi* buffaloes in Azad Kashmir, Pakistan. *J. Anim. Plant Sci*., **16**(1-2): 15-19.

Jabbar, M.A., M.I. Anjum, S. Rehman and W. Shahzad. 2006. Comparative efficiency of sunflower meal and cottonseed cakes in the feed of crossbred calves for meat production. *Pak. Vet. J*., **26**(3): 126-128. Available on: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.543.1879&rep=rep1&type=pdf

Khanum, S.A., M. Husain, L. Jabar, R. Kausar, A.M. Chema and M.A. Jabar. 2012. Effect of concentrate supplementation on age at maturity in growing buffalo heifers. *J. Anim. Plant Sci*., **2**2: 329-331.

Matthews, C.D., M.V. and J.R. Deed. 1993. Melatonin and photoperiodic time measurement. Seasonal breeding in the sheep. *J. Pineal Res*., **14**: 105-116. Available on: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1600-079X.1993.tb00493.x

Nanda, A.S., P.S. Brar and S. Prabhakar. 2003. Enhancing reproductive performance in dairy buffalo: Major constraints and achievements. *Reproduction Supplement*, **61**: 27-36. Available on: https://www.biosciproceedings.org/bp/0005/pdf/bp0005rdr3.pdf

Naqvi, A.N. 2000. Effect of parity and season of calving on service period in Nili-Ravi buffaloes in Pakistan. *Asian Austral. J. Anim*., **13**(3): 287-291. DOI: 10.5713/ajas.2000.287

Papachristoforou, C., A. Koumas and C. Photiou. 2000. Seasonal effects on puberty and reproductive characteristics of female Chios sheep and Damascus goats born in autumn and in February. *Small Ruminant Res*., **38**(1): 9-15. DOI: 10.1016/s0921-4488(00)00143-7

Park, C.S., R.B. Danielson, B.S. Kreft, S.H. Kim, Y.S. Moon and W.L. Keller. 1998. Nutritionally directed compensatory growth and effects on lactation potential of developing heifers. *J. Dairy Sci*., **81**(1): 243-249. DOI: 10.3168/jds.S0022-0302(98)75572-9

Parmeggiani, A., Di Palo R., L. Zicarelli, G. Campanile, L. Esposito, E. Seren, P.A. Accorsi and S.M. Soflai. 1994. Melatonina e stagionalità riproduttiva della bufala. *Agricoltura e Ricerca*, **153**: 41-48.

Perera, B.M.A.O. 2011. Reproductive cycles of buffalo. *Anim. Reprod. Sci*., **124**(3-4): 194-199.

Rosa, H.J.D. and M.J. Bryant. 2003. Seasonality of reproduction in sheep. *Small Ruminant Res*., **48**(3): 155-171. DOI: 10.1016/S0921-4488(03)00038-5

Saha, S., D.K. Sadana and S. Saha. 2000. Effect of genetic and non-genetic factors on reproduction traits in Murrah buffaloes. *Indian J. Anim. Health*, **39**(1): 41-42.

Singh, R.V. and A.E. Nivasarkar. 2000. Production and reproduction potential of Bhadawari buffaloes. *Buffalo J*., **16**(2): 163-173.

Suhail, S.M., M.S. Qureshi, S. Khan and Ihsanullah. 2009. Inheritance of economic traits of dairy buffaloes in Pakistan. *Sarhad Journal of Agriculture*, **25**(1): 87-93.

Terzano, G.M., L.B. Vittoria and A. Borghese. 2012. Overview of reproductive endocrine aspects in buffalo. *Journal of Buffalo*

*Science*, **1**: 126-138. DOI: 10.6000/1927-520X.2012.01.02.01

Thevamanoharan, K. 2002. *Genetic analysis of performance traits of swamp and Riverine buffalo*, Ph. D. Thesis, Katholieke University Leuven, Belgium.

Zicarelli, L. 1997. Reproductive seasonality in buffalo. *In Proceedings of the 3th International Course of Bio-Technology in Buffalo Reproduction*, Napoli, Italy.