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ESTIMATED BREEDING VALUES FOR 305 DAYS MILK YIELD TRAITS AND SIRE RANKING OF *NILI-RAVI* BUFFALOES IN PAKISTAN

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ABSTRACT

Pedigree records of 2,881 buffaloes sired by 162 bulls from four Livestock Experiment Stations in Punjab, Pakistan were used. The objective of this study was to estimate the breeding values of animals for different traits to rank the sires and estimation of genetic trends. An Animal Model incorporating all known relationships was used for estimating variance components and breeding values. The estimation of (co)variances and breeding values were obtained using the Derivative Free Restricted Maximum Likelihood (DFREML) set of computer program. The JAA computer program was used for the estimation of reliability of breeding values. The mean estimated breeding value for 305-day milk yield (kg), was -23±287 kg, with an overall genetic trend of +3.5 kg ranged -3.4 to 10.2 kg among different herds. Sires were ranked based on their breeding values along with reliability. 305 days milk yield regression line showing negative genetic trend (Y = -58.084+3.870X). Genetic trend in the recent past decade was negative for the trait indicating that selection strategy especially for choosing young bulls in the artificial insemination program and progeny testing needs to be reevaluated.

Keywords: *Bubalus bubalis*, buffaloes, EBV, Sire summary, 305-days milk yield, *Nili-Ravi* buffaloes

INTRODUCTION

Buffalo (*Bubalus bubalis)* is most suitable specie to perform in tropics (Faraz *et al*., 2021*a*) as it provides milk and meat of great economic importance (Faraz *et al*., 2021*b*). In a dairy herd, the selection for female replacement; scope is always limited due to increase in number while in males, it is easy as there is less number required for breeding of females. Achieving genetic improvement involves the identification of those animals with the best breeding values and then ensuring that the selected individuals become parents of the next generation.

Selection for milk yield in dairy cattle is generally based on the analysis of 305-day lactation records. To estimate 305-day lactation yields, incomplete lactation records are usually extended to 305-day records. In most of studies, the sires and cows have been evaluated genetically based on 305-day-milk yield, comprising monthly TD records during lactation with the aim of improving the selection strategies for genetic improvement in

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dairy science (Cilek *et al*., 2008).

Breed improvement reforms in buffalo are very limited and except for Italian studies, limited population data have been used to estimate the genetic trends. Negative genetic trend in yield and other traits have been reported for *Nili-Ravi* and Murrah buffaloes (Khan, 1998; Thevamanoharn, 2002; Dutt *et al*., 1996). Catillo *et al*. (2001) on the other hand reported that milk yield increased by 1 kg per year during 1974 to 1996 instead of 4.6 kg per year reported previously (1975 to 1990) by Pilla and Moiloi (1992) for Italian buffaloes.

As implementation of a breeding program in buffalos, requires genetic variation and estimation of genetic parameters and breeding values. For the study of the genetic makeup of a population the prime consideration is of heredity and environmental factors which are affecting it. Estimation of genetic parameters for different productive and reproductive traits of *Nili-Ravi* buffaloes in Pakistan have previously been based on the intra-sire regression of daughter on dam and covariance of paternal half-sibs, with pre-adjustment of fixed effects in the model. Breed improvement program in buffalo in Pakistan are new (Khan, 2002) but their expansion to more institutional and private herds require estimates of genetic parameters and genetic correlation among economic traits.

The present study aimed to estimate the breeding values of some productive and reproductive traits in *Nili-Ravi* buffaloes for identification of superior animals and genetic trends.

MATERIALS AND METHODS

All records of *Nili-Ravi* buffaloes were obtained from the four Government institutional herds in Punjab namely Haroonabad, District Bahawalnagar; (1979 to 2000); Chak Katora, District Bahawalpur (1971 to 2000); Khushab, District Khushab (1979 to 2000) and Livestock Production Research Institute Bahadurnagar, District, Okara (1971 to 2000) Punjab, Pakistan was utilized for the present study.

Data were collected on date of calving, sire's date of birth, date of drying, dam's date of birth, date of disposal, date of service, number of services per conception and lactation milk yield. The derived variables were 305-day lactation milk yield, lactation length, dry period, age at first calving, calving interval, service period and gestation period.

Data on milk yield (305-day and total) was based upon actual weekly milk records. Lactations shorter than 60 days were excluded (5.23%). Incomplete lactation records of buffaloes due to culling abortion or diseases were also excluded.

The calving months were grouped into four seasons, winter (December to February); spring (March to May); summer (June to August) and autumn (September to November), (Dahlin, 1998; Das and Sharma, 1994).

Estimation of parameters

Heritabilities and repeatabilities were determined by analyzing records from all lactations, with the same data set as described above, in a univariate repeatability model:

$$Y = Xb + Zu + Wc + e$$

In this, the parameters are like above except the W and c, here represents the design matrix and the vector, respectively, of random permanent environmental effects of the individual. In this model, the calving age was ranked within the lactation number. Assumptions were as for the univariate model above except E(c) = 0,

Var(c) = $I\sigma^2_c$ and Ver(y) = $ZA\sigma^2_a Z' + WI\sigma^2_a W + R$.

Covariances of the three effects were, all assumed to be zero.

The estimation of (co) variances was conducted using the Derivative Free Restricted Maximum likelihood (DFREML) set of computer program (Meyer 1997), which carries out multivariate analysis by REML originally based upon derivative free approach. The program allowed missing records in the multivariate analysis. The Simplex and Powell algorithm was found to be slow to reach maximum likelihood in bi-and multivariate analysis, whereas the AI-REML was not.

The DFREML package was used to attain the predicted breeding values for each trait. The C^2 variance component was estimated by the univariate analysis to estimate the repeatabilities as under:

$$C^2 = \sigma^2_{PE} / \sigma^2_P$$

$$r = \sigma^2_{PE} + \sigma^2_A / \sigma^2_P$$

Where;

C^2 = common environmental variances

σ^2_{PE} = permanent environmental variances

σ^2_P = phenotypic variances

σ^2_A = Additive genetic variance

R = Repeatability

Estimation of breeding values and genetic trends

The estimates of genetic variances obtained from the above analysis were used as starting values for the estimation of breeding values by Best Linear Unbiased Prediction procedure as outlined by Henderson (1973). The model used for this purpose was an animal model. The JAA (Misztal, 1997) Computer program was used for the estimation of breeding values and reliability. The breeding values of the cows were fitted in a fixed effect model having year of birth as the only fixed effect. The breeding values and the reliabilities were used for the ranking of the sires. The breeding values least squares were fitted against birth year to show the genetic trend. Different phenotypic performance traits were put against the birth year to depict phenotypic trends.

RESULTS AND DISCUSSIONS

The estimated breeding values (EBVs) for different economic traits are presented in Table 1 both for bulls and buffaloes. Buffaloes estimated breeding values had a wider range for all the traits indicating that criteria for the selection of bull dams can be made stricter to improve genetic gain in traits like milk yield and age at first calving. Estimated breeding values for bulls also indicated that there is great potential to improve economic traits. For 305-day milk yield reliability was also estimated and are presented with EBVs of bulls. Out of 162 bulls, 13 bulls had reliabilities ≥90%, while 47 (29%) bulls had reliability ≥70%. Low reliabilities indicated lack of information (mainly on daughters) and lower h2 estimates (Table 2).

The genetic trend of the buffalo population for 305-day milk yield is presented in Figure 1. An increasing trend was observed for 305 days milk yield (3.9 kg/year) during the period under study. Most of the increase was during 1971 to 1979 (13.7

kg/year). For 1980 to 1988, the average increase in EBVs was 7.7 kg/year, while during the most recent period (1989 to 1997), average change in EBVs was -4.5 kg/year which indicated that genetically superior bulls were not judiciously used in the recent years (Figure 1). Within herd genetic trends were not uniform, positive genetic trend of 10.2 kg /year was estimated for LESHA. For LESCK, LESHA and LPRIBN, trends were 5.42, -3.37 and 3.15 kg/year, respectively. Previously reported genetic trend for *Nili-Ravi* buffaloes pertains to LPRIBN (Khan, 1998; Thevamanoharan, 2002), where genetic trend in 305-day milk yield was reported to be close to zero which may be due to choice of birth years. Genetic trends in other buffalo population have been quite variable. In the Indian buffaloes, positive genetic trend has been reported (Yadav *et al*., 1983), while negative genetic trend was reported by Dutt *et al*. (1996). The annual genetic trend in Egyptian buffaloes was reportedly positive but non-significant (Khattab and Mourad, 1992; Aziz, 1994; Metry *et al*., 1994). For Italian buffaloes, Pilla and Moioli (1992) reported that the genetic gain in milk yield was 4.6 kg/year, while Catillo *et al*. (2001) reported it to be 2.1 kg for bulls and 1 kg for all population. One of the main reasons for low genetic gains in buffaloes has been that extensively used bulls have inferior breeding values (Khan, 1998). Use of natural matings may be partially responsible as EBVs estimation were generally not available when their bulls were chosen. Problem with performance recording and identification of pedigree has also been mentioned for lower genetic gain. Moioli *et al*. (2000) summarized reports of Azerbaijan, Bulgaria, Iran, Italy, Pakistan, India, Egypt and concluded that although, animal recording is a prerequisite for any serious effort to develop livestock production at farm, industry or national level, situation for buffaloes was not encouraging. Data collected through recording activities could be used for extension services at farm and industrial level to estimation of breeding values, selection of bulls and bull mothers at farm level and national level and planning improvement strategies for buffalo in the country. Less than 1 percent of buffalo populations are recorded and experimental herds remain the only source for genetic studies. This seems to have not changed much in the last five years.

The genetic trends for lactation length, dry period, age at first calving, caving interval and service period are presented in Figures 2, 3 and 4. Trend in lactation length had a pattern similar to 305-day milk yield. It increased 5 days/year. The dry period did not have any specific genetic trend but age at first calving decreased by -2.8 days/year which is favorable. The calving interval and service period on the other hand increased by 1 day/year, which is not favorable. Various studies have reported genetic trends in economic traits other than milk yield. For age at 1st calving for example, Italian buffaloes were reported to have no trend (Catillo *et al*., 2001), while Reddy and Taneja (1984) reported it to be in right direction in Murrah buffaloes. The study, however, pertained to an experiment station only. The genetic trend for different productive and reproductive traits indicated that the breeding program for buffaloes needs to be evaluated for all the institutional herds. The overall increase in EBVs for some of the herds for the study period may be encouraging. Trends for the last decade are however disappointing as the genetic ability of buffaloes deteriorated, opposite expectations, with the introduction of artificial insemination, direction of genetic gain is expected to be positive. This could happen if young bulls are chosen on EBVs of their parents, instead of some

Table 1. Estimated breeding values (EBVs) for bulls and buffaloes in the four institutional herds.

Traits	EBVs of bulls			EBVs of buffaloes		
	N	Mean±SD	Range	N	Mean±SD	Range
305-day milk yield (kg)	162	-23±287	-1145 to 773	2706	-23±315	-1381 to 1403
Total milk yield (kg)	162	-17±337	-1152 to 938	2706	-24±373	-1471 to 1994
Lactation length (days)	162	-17±337	-1152 to 939	2706	-24±372	-1472 to 1993
Dry period (days)	152	12±47	-83 to 146	2398	3±59	-152 to 229
Age at first calving (days)	119	-11±115	-296 to 341	2148	2±143	-549 to 2033
Calving interval (days)	131	-17±42	-131 to 102	2046	-25±51	-190 to 168
Service period (days)	145	11±49	-133 to 147	2249	-0.3±64	-190 to 263
Services per conception (No.)	162	-0.06±0.33	-0.9 to 1.2	2689	-0.12±49	-0.8 to 1.2
Gestation period (days)	162	0.05±0.73	-3.9 to 1.6	2705	0.05±0.74	-5.2 to 2.6

Table 2. Estimated breeding values (EBV) and reliability (Rel%) for 305-day milk yield (kg) among different sires.

Name of sire	Sire code	Date of Birth	EBV	Rel (%)
25/3.7	474102537	07/18/47	190.17	50
40/2.5	534104025	06/30/53	-190.89	21
1/1.6	546100116	02/04/54	156.51	20
74/3.0	544107430	05/03/54	310.19	33
51/3.5	554105135	07/10/55	-531.57	79
57/3.5	554105735	09/13/55	55.41	30
65/3.5	554106535	09/18/55	-920.80	58
40/3.0	564104030	03/27/56	36.13	55
30/2.6	564103026	06/06/56	407.35	59
83/2.6	564108326	06/21/56	773.88	68
2/2.8	586100228	05/12/58	-214.65	21
93/4.8	584109348	10/31/58	-320.35	83
67/3.9	594106739	09/22/59	-546.05	87
33/3.3	624103333	11/08/62	-124.44	21
B/137	636100137	05/03/63	-110.51	23
15/3.3	635101533	07/19/63	-875.89	93
53/4.3	634105343	10/05/63	89.59	90
43/3.5	654104335	08/31/65	-502.35	75
SHEIKH	656100445	10/12/65	298.21	46
17/2.6	664101726	05/11/66	-1145.45	61
23/2.6	664102326	06/05/66	199.10	28
66/4.6	664106646	10/12/66	374.93	89
10/2.7	674101027	05/05/67	-248.69	82
51/4.8	685105148	10/05/68	-132.77	93
54/4.8	685105448	10/17/68	-658.11	79
64/4.8	684106448	12/07/68	6.71	46
3/1.9	694100319	01/21/69	307.13	79
GOHAR 569	696156929	02/21/69	422.80	96
29/3.9	695102939	07/05/69	-210.45	35
50/3.9	695105039	08/31/69	225.71	61
62/4.9	695106249	10/29/69	78.70	94
61/4.9	695106149	10/29/69	-174.17	88
63/4.9	694106349	11/14/69	-227.30	75
LHR48	716100048	03/04/71	181.34	22
25/3.1	714102531	07/21/71	-17.89	26
UN3/2.3	716100101	07/21/71	-230.88	28

Table 2. Estimated breeding values (EBV) and reliability (Rel%) for 305-day milk yield (kg) among different sires. (Continue).

Name of sire	Sire code	Date of Birth	EBV	Rel (%)
333	714100333	07/21/71	-340.62	25
36/3.1	714103631	08/25/71	-125.56	35
43/3.1	714104331	09/15/71	390.75	86
51/4.1	714105141	10/15/71	338.59	65
P1	722100001	02/04/72	-96.58	37
RUSTAM	726100001	02/04/72	-112.89	97
P5	726100005	03/10/72	-153.75	61
22/2.2	724102222	05/26/72	-609.80	71
42/3.2	724104232	08/04/72	-50.03	21
BABAR	736102523	04/02/73	97.33	51
28/3.3	735102833	07/26/73	111.82	90
35/3.3	734103533	08/17/73	-357.37	72
53/3.3	734105333	09/26/73	347.08	70
K7/1.4	744100714	01/19/74	101.58	19
18/3.4	745101834	03/21/74	75.00	78
BP07	746100007	04/04/74	-470.92	70
P4	744100004	04/16/74	-177.52	66
3/2.5	755100325	04/06/75	-98.33	85
7/2.5	754100725	04/13/75	-287.76	23
15/2.5	754101525	07/01/75	-74.39	22
Dawn	756108535	08/04/75	-136.25	95
65/3.5	756106535	08/09/75	-19.97	23
988	756100988	12/11/75	-248.72	46
42/3.6	764104236	07/31/76	307.78	32
39/4.6	764103946	10/27/76	381.28	73
P2	766100002	10/27/76	118.82	78
Gul	766108646	12/11/76	82.24	95
KP20	786100020	06/05/78	203.21	24
KP19	786100019	06/06/78	-12.82	79
42/4.6	784104246	06/16/78	107.87	38
19/4.9	796101949	12/11/79	-351.77	50
B61	804100061	01/09/80	41.43	25
KING P2	802100002	03/03/80	103.33	93
B62	804100062	08/17/80	-53.38	78
B64	804100064	08/24/80	-69.12	81
B63	804100063	09/11/80	359.49	70

Table 2. Estimated breeding values (EBV) and reliability (Rel%) for 305-day milk yield (kg) among different sires. (Continue).

Name of sire	Sire code	Date of Birth	EBV	Rel (%)
UN3/3.0	806100067	09/17/80	50.40	60
B067	804100067	09/17/80	-118.81	22
B038	806100038	10/06/80	254.96	50
B066	804100066	11/01/80	177.98	56
B065	804100065	11/15/80	144.99	77
B68	804100068	12/23/80	-8.91	82
B89	814100089	07/01/81	351.47	62
B90	814100090	07/07/81	-343.23	81
9/3.1	813100931	08/04/81	233.84	77
B94	814100094	08/30/81	-246.18	64
B69	814100069	09/05/81	476.88	54
34/3.1	814103431	09/16/81	281.63	35
B93	814100093	09/16/81	172.77	54
K45/3.1	812104531	09/17/81	407.50	92
B95	814100095	10/17/81	36.54	27
B96	814100096	12/26/81	-84.02	48
KD4	826100004	03/05/82	-165.34	43
23/2.2	824102322	04/27/82	-21.42	22
B77	826100077	06/08/82	473.82	67
UN2/2.2 (B100)	826100100	06/22/82	195.86	24
B101	824100101	06/29/82	85.72	46
B111	824100111	07/10/82	0.34	63
UK8/3.2 (B120)	826100120	09/21/82	106.48	59
B120	824100120	09/21/82	-32.97	27
NEELA 51/4.2	822105142	12/13/82	-80.28	90
B126	836100126	04/26/83	-222.64	24
B130	834100130	06/08/83	-174.44	59
B134	836100134	08/15/83	64.42	52
B143	836100143	09/16/83	155.73	56
BP42	836100042	09/22/83	499.26	69
B156	846100156	01/01/84	-55.58	25
B170	846100170	05/16/84	-58.82	22
B177	846100177	08/01/84	-79.84	23
PHALIL25/34	842102534	08/09/84	123.03	90
P227	846100227	08/15/84	-12.96	53
163/3.4	843116334	08/24/84	43.06	89

Table 2. Estimated breeding values (EBV) and reliability (Rel%) for 305-day milk yield (kg) among different sires. (Continue).

Name of sire	Sire code	Date of Birth	EBV	Rel (%)
B174	846100174	09/20/84	-25.87	24
KOONJ44/4.4	842104444	10/04/84	-195.86	86
B.237	844100237	10/23/84	78.58	31
B239	844100239	12/02/84	769.41	63
B214	856100214	04/15/85	-178.09	27
311	856100311	07/24/85	-67.43	22
KD6	856100006	07/24/85	-103.89	28
B247	854100247	10/04/85	93.94	34
B242	854100242	10/12/85	-213.31	57
248	854100248	10/26/85	53.73	74
59/45	854105945	11/19/85	-101.60	27
305	856100305	12/19/85	363.43	51
253	866100253	02/15/86	74.98	70
B255	866100255	02/21/86	34.70	22
B246	864100246	05/09/86	10.77	49
Chinba	861100136	07/01/86	93.30	60
24/3.6	862102436	07/10/86	-66.70	88
B265	866100265	07/14/86	319.38	46
Roojh	862102736	07/17/86	67.33	53
B260	864100260	08/04/86	107.21	42
B300	863100300	08/19/86	-102.37	35
315	866100315	10/02/86	76.84	22
83/46	864108346	10/29/86	7.46	17
339	874100339	05/03/87	-46.69	14
B332	874100332	05/08/87	430.90	33
333	874100333	05/08/87	27.73	19
P2	876100002	05/08/87	-13.51	17
P1	876100001	05/08/87	-113.95	33
B321	874100321	09/18/87	-128.95	38
254	876100254	09/27/87	-8.92	17
B320	874100320	11/12/87	-4.99	19
334	874100334	11/23/87	-472.36	22
333	884100333	10/01/88	-865.16	41
H27/4.8	883102748	10/04/88	55.21	66
B334	884100334	11/23/88	47.62	48

Table 2. Estimated breeding values (EBV) and reliability (Rel%) for 305-day milk yield (kg) among different sires. (Continue).

Name of sire	Sire code	Date of Birth	EBV	Rel (%)
H28/4.5	883102845	12/11/88	-385.99	80
H16/1.9	891101619	05/03/89	-344.43	31
B351	894100351	07/18/89	34.57	29
KD5	896100005	12/17/89	-117.25	24
B418	916100418	07/26/91	92.09	22
43/3.1	913104331	09/22/91	-273.79	20
PHOOL46/4.2	922104642	11/24/92	61.14	24

physical traits only. Some of these issues have been discussed earlier (Khan *et al*., 1999) and evidence from Sahiwal breed under the same managemental setup indicates that strategy of choosing young bulls might need modification (Bhatti, 2007).

REFERENCES

Aziz, A.M. 1994. Sire evaluation and environmental and genetic trends of milk yield of water buffaloes, Alexandria. *J. Agric. Res*., **39**(2): 129-148.

Bhatti, A.A., M.S. Khan, Z. Rehman, A.U. Hyder and F. Hassan. 2007. Selection of Sahiwal cattle bulls on pedigree and progeny. *Asian-Austral. J. Anim. Sci*., **20**. DOI: 10.5713/ajas.2007.12

Cady, R.A., S.K. Shah, E.C. Schermerhorn and R.E. McDowell. 1983. Factors affecting performance of *Nili-Ravi* buffaloes in Pakistan. *J. Dairy Sci*., **66**(3): 578-586.

Catillo, G., B. Moioli and F. Napolitano. 2001. Estimation of genetic parameters of some productive and reproductive traits in Italian buffalo. Genetic evaluation with BLUP-animal model. *Asian-Austral. J. Anim. Sci*., **14**(6): 747-753. Available on: https://www.animbiosci.org/upload/pdf/14-106.pdf

Cilek, S., H. Orhan and A.K.E.H. Sahin. 2008. Estimation of breeding values of Anatolian population of Simmental cows using test day milk yields. *Arch. Zootech*., **11**: 79-85. Available on: https://ibna.ro/arhiva/AZ%2011-4/AZ%2011-4%2009%20Cilek-updated.pdf

Dahlin, A. 1998. *Genetic studies on Sahiwal cattle in Pakistan*. Ph.D. Thesis, Swedish University Agricculture Sciencse, Uppsala, Sweden.

Dutt, T., K.L. Raheja and V.K. Taneja. 1996. Estimation of sires breeding values and genetic and phenotypic trends for various economic traits in Murrah buffaloes. *Indian J. Anim. Sci*., **66**: 1145-1148.

Faraz, A., N.A. Tauqir, A. Waheed and A. Hameed. 2021a. Effect of exogenous oxytocin administration on the performance of lactating Nili Ravi buffalo. *Iranian J. Appl. Anim. Sci*., **11**(3): 517-525.

Faraz, A., A. Waheed, N.A. Tauqir, H.M. Ishaq, F. Iqbal and Z. Huma. 2021. Feedlot performance and serum profile of buffalo (Bubalus bubalis) calves under high input feeding systems. *Buffalo Bull*., **40**(2): 325-333. Available on: https://kuojs.lib.ku.ac.th/index.php/BufBu/article/view/2981

Henderson, C.R. 1973. Sire evaluation and genetic trends, p. 10-41. *The Proceedings of the Animal breeding and Aenetics Symposium in Honor of Dr. Jay L. Lush*, Virginia Polytechnic Institute and State University, American Society of Animal Science and American Dairy Science Association, Virginia, USA.

Khan, M.S. 1998. Animal model evaluation of *Nili-Ravi* buffaloes. *The Proceedings of the 6th World Congress on Genetics Applied to Livestock Production*, University of New England, Armidale, Australia.

Khan, M.S. 2000. Lactation length adjustment in *Nili-Ravi* buffalo: A new procedure. *Buffalo Newsletter*, **14**: 4-5.

Khan, M.S., M.A. Chaudhary and M.M. Bhatti. 1999. Progeny testing in *Nili-Ravi* buffaloes: Ranking of bulls for first six batches. *Buffalo Newsletter*, **13**: 1-5.

Khattab, A.S. and K.A. Mourad. 1992. Estimation of genetic parameters and genetic trends for some milk traits in a herd of Egyptian buffaloes. *Egyptian Journal of Animal Production*, **29**(2): 173-184.

Metry, G.H., H.A. El-Rigalaty, J.C. Wilk and R.E. McDowell. 1994. Factors affecting the performance of Egyptian buffalo. *Annals of Agricultural Science*, **32**(2): 827-841.

Meyer, K. 1997. Estimation of variance components with large-scale dominance models. *J. Dairy Sci*., **80**(5): 965-974. DOI: 10.3168/jds.S0022-0302(97)76021-1

Misztal, I. 1997. *Sparsem Collection of Sparse Matrix Modules for Fortran 90*. Available on: http://nce.ads.uga.edu/~ignacy/f90 or at ftp://num.ads.uga.edu

Moioli, B., J. Mäki-Hokkonen, S. Galal and M. Zjalic. 2000. Animal recording for improved breeding and management strategies for buffaloes. *The Proceedings of the Workshop Held in Bled*, Slovenia.

Pilla, A.M. and B.M. Moioli. 1992. Genetic evaluation of buffaloes for milk yield using the animal model. *Zootech Nutr. Anim*., **18**(5): 207-218.

Reddy, C.E. and V.K. Taneja. 1984. A note on factors influencing the first lactation traits of *Nili-Ravi* buffaloes. *Indian J. Dairy Sci*., **37**(1): 36-39.

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

Yadav, K.N., S.S. Rathi, S. Rau and R. Singh. 1983. Estimates of genetic and phenotypic trends in Murrah buffaloes under progeny testing programme. *Indian J. Dairy Sci*., **36**: 320-330.