Breeding Prolific Garole with Malpura Sheep for Increased Reproductive Efficiency in Semi Arid Tropics of India

R. C. Sharma*, A. L. Arora, A. K. Mishra, S. Kumar and V. K. Singh
Division of Animal Genetics and Beeding, Central Sheep and Wool Research Institute
Avikanagar-304 501, Rajasthan, India

ABSTRACT : Garole, a prolific small sized sheep breed of West Bengal, was introduced in the Mutton project of the Institute in 1997 to explore the possibility of incorporating fecundity gene(s) into monotocus Malpura sheep of Rajasthan. Results of reproduction and production traits in respect of Garole×Malpura (G×M) half-breds have been obtained. Of 35 lambing obtained so far from the ewes of Garole×Malpura, 45.71% were twin lambing, whereas, Malpura sheep produced mostly single lamb except 2.55% twin lambing on an average. Other reproduction traits in G×M ewes such as lambing rate, litter size at birth and weaning were considerably improved over Malpura ewes. Results revealed that the fecundity genes responsible for increasing ovulation rate and litter size have been incorporated in to the G×M genotype and it might prove a valuable germ plasm towards evolving a new prolific strain of sheep. Interestingly, survivability of G×M half-breds was almost at par with the local Malpura sheep in harsh climatic conditions of semi-arid tropics. The body weights at different ages of G×M half-breds were on little lower side compared to contemporary Malpura lambs. Average kilogram of lambs weaned/ewe lambed in Malpura and G×M genetic group was 11.86 and 11.07 kg respectively. In view of minimizing the differences in body weights and kg of lambs weaned/ewe lambed between the two genetic groups, G×M ewes has to be backcrossed with Malpura rams to raise the inheritance of latter up to 75% level. However, further research is needed to reach on certain conclusions regarding net returns from such crosses. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 6 : 737-742)***

Key Words : Reproduction, Garole Crosses, Sheep, Performance Traits

INTRODUCTION

Reproductive efficiency of the ewe is a component of prime concern in sheep breeds of India because it affects the overall flock productivity as well as net returns of the sheep rearing. Mostly sheep breeds of India are monotocus barring Garole (Sharma et al., 2001), a small sized breed of sheep found in hot humid coastal belt of Sunderban in Southern part of West Bengal and is a highly prolific breed of sheep (Ghalsasi and Nimbkar, 1993; Sharma et al., 1999a; Davis et al., 2002; Nimbkar et al., 2003a,b). It is speculated that ancestors of Garole sheep were imported by Australia from Bengal in late 18th century and these sheep might have contributed prolificacy to the Booroola Merino evolved in Australia (Turner, 1982).

With the aim to augment the reproductive rate of monotocus Malpura sheep through incorporating the fecundity gene(s) responsible for increasing ovulation rate and litter size, Garole sheep was introduced during 1997 in Sheep Breeding for Mutton Production Project of the Central Sheep and Wool Research Institute, Avikanagar located in semi-arid region of the country. Bulk of sheep are being reared in semi arid and arid tropical tract of the country and they are monotocus in nature. Malpura is an important native mutton breed of Rajasthan having open coarse wool texture and reared primarily for meat purposes. Selective breeding is being practised mainly to enhance the body weights of the lambs and fat lamb production. Since, Garole rams are small sized and weigh 14-15 kg at maturity, therefore, Malpura ewes were inseminated artificially by fresh diluted semen of Garole rams. The cross breeding program continued since 1997 and more than 300 Garole× Malpura half-breds have so far been produced through cross breeding and interbreeding among half-breds. Results on reproductive performance, growth and survivability of Garole×Malpura half-breds have now become available. The present study has, therefore, been designed for comparative evaluation of these crossbreds with Malpura sheep so that further breeding and selection strategy could be formulated.

* Corresponding Author: R. C. Sharma. Equine Production Campus (NRCE) Post Bag No. 80, Bikaner-334 001, Rajasthan, India. Tel: +91-151-2232541, Fax: +91-151-2230114, E-mail: rcs harma@cswri.raj.nic.in
Received June 15, 2003; Accepted January 10, 2004

MATERIALS AND METHODS

Location

The study was conducted in the Division of Animal Genetics and Breeding sheep farm at Central Sheep and Wool Research Institute, Avikanagar located at 75°-22′E longitude and 27°-17′N latitude and an altitude of 320 m above mean sea level. The climate of the location is typically hot semi arid with yearly mean minimum and maximum temperature of 4 and 46°C, respectively. The rainfall is erratic and mainly occurs during the month of

July to August with precipitation ranges from 400 to 700 mm per annum.

Experimental animals and their management

Malpura, a native large sized mutton sheep of semi arid region of Rajasthan, was used as dam breed and Garole, a native small sized prolific meat sheep of hot humid region of West Bengal, was used as sire breed in developing Garole×Malpura half-breds that supposed to have fecundity genes. Garole×Malpura lambs included in the study were obtained by two means: 1. From crossing of Malpura ewes with Garole ram by artificial insemination (AI) with fresh diluted semen. 2. From inter breeding among G×M halfbreds. Controlled breeding was adopted in both the genotypes and male flock has always been kept separate from female flocks. Heat detection was performed daily in the morning and evening hours with the help of approned rams and ewes were mated in accordance to breeding plan. More than 95% ewes were tupped during Autumn breeding season (mid August to mid October) every year and rest ewes were bred during following Spring season (ending February to through March). The cross breeding of Malpura ewes with fresh diluted semen of Garole rams through AI was attempted during the Autumn breeding season only. The contemporary Malpura lambs were produced through selective breeding in Malpura sheep. Reproduction traits on Garole×Malpura ewes started to become available from the year 2000.

All the sheep were raised under semi-intensive management system and provided similar grazing/feeding conditions. An extra allowance of concentrate @ 250 g/ewe/day was supplemented under group feeding for three months every year i.e. from last month of pregnancy to completion of 2nd month of lactation over and above of 8-10 h grazing in the field interspersed with seasonal shrubs and forbs. The lambs were remained with the mothers in the lambing pen individually for the first 3-4 days after parturition. After that ewes were put on natural pastures for grazing during the day and brought back in the sheds during mid- day hours for milk suckling by the lambs in first fortnight of parturition. The lambs were allowed to suckle their dams from birth until weaning at 3 months of age. At the sheds lambs were fed tree/pala leaves (*Zizyphus rotundifolia*), cowpea (*Vigna sinensis*) fodder and concentrate mixture *ad libitum* from 20 days to weaning. The lambs were on pasture for grazing and exercise after one month of age and onwards. In addition to daylong grazing on natural vegetation, 250 g concentrate mixture

Table 1. Least squares means for body weights (kg) in Malpura lambs

Particulars	Body weights at			
	Birth	3 month	6 month	12 month
Overall	2.97±0.02 (622)	12.35±0.11 (576)	19.28±0.19 (401)	27.90±0.20 (314)
Sex	**	**	**	**
Male	3.03±0.02 (316)	12.87±0.15 (293)	20.86±0.31 (130)	31.21±0.34 (78)
Female	2.90±0.02 (306)	11.84±0.1 (283)	17.69±0.21 (271)	24.59±0.19 (236)
Year	**	**	**	**
1998	3.02±0.03 (164)	11.04±0.22 (143)	17.02±0.35 (102)	25.51±0.34 (80)
1999	3.06±0.03 (168)	12.66±0.21 (160)	19.00±0.33 (114)	26.95±0.31 (91)
2000	2.88±0.04 (127)	13.24±0.24 (117)	21.09±0.42 (72)	29.79±0.42 (57)
2001	2.91±0.03 (163)	12.48±0.21 (156)	19.98±0.34 (113)	29.35±0.33 (86)
Regression ewe's wt.	**	**		
	0.057±0.01	0.21±0.03	-	-

** $p<0.01$; Within parentheses are number of observations.

Table 2. Least squares means for average daily gain (g) in Malpura lambs

Particulars	Average daily gain (ADG)		
	0-3 month	3-6 month	6-12 month
Overall	103.94±1.16 (576)	72.62±1.11 (401)	39.91±0.65 (314)
Sex	**	**	**
Male	109.08±1.62 (293)	81.57±1.81 (130)	43.16±1.12 (78)
Female	98.80±1.64 (283)	63.67±1.25 (271)	36.67±0.63 (236)
Year	**	**	**
1998	88.61±2.36 (143)	63.43±2.04 (102)	39.19±1.11 (80)
1999	106.15±2.18 (160)	63.99±1.93 (114)	37.23±1.03 (91)
2000	114.91±2.57 (117)	83.47±2.45 (72)	39.63±1.38 (57)
2001	106.09±2.21 (156)	79.59±1.97 (113)	43.62±1.08 (86)
Regression ewe's weight	**		
	1.78±0.34	-	-

** $p<0.01$; Within parentheses are number of observations.

was provided through out the post-weaning period (3-12 months of age) of the lambs. Washed sheep were shorn manually twice a year, in spring (March-April) and autumn (September-October). Post shearing dipping was performed only for spring shearing season. All the prophylactic measures against various sheep diseases were carried out as per prescribed health calendar of the Institute in addition to curative treatment of sick animals as and when required.

Performance records and their analysis

Growth profile data, collected during 4 years (1998-2001) on birth weight, 3, 6 and 12 month body weight with an accuracy of 50 g of 622, 576, 401 and 314 lambs, respectively pertaining to Malpura and 230, 211, 204 and 121 lambs, respectively belonging to Garole×Malpura maintained at the Institute sheep farm were utilized for the present study. Data on growth profile traits were classified according to sex of lamb and year of lambing in Malpura, whereas in G×M, these were classified as sex of lamb, year of lambing, dam breed and type of birth. Effect of ewe weight on birth and weaning weight of lambs was also computed by taking the ewe weight as regression in statistical model. Least squares procedures (Harvey, 1975) were used to analyse the growth data. Tests of significance were based on the residual mean squares. Reproductive performance and survivability of the sheep of both the genotypes were compiled on annual basis. The "ewe productivity efficiency" in terms of kilogram (kg) weaned at 3 month age of lamb per ewe lambed was calculated as

Kg weaned/ewe lambed=Sum total of weaners' weight during a year/Total number of ewes lambed during a year

Lambing rate (%)=(Number of lambs born in a year/ Number of ewes becomes available in a year)×100

RESULTS AND DISCUSSION

Growth

As the Garole is a small sized breed and was crossed with large sized Malpura ewes, it is quite natural that half-bred progenies born out from such crosses would weigh less than the dam parent and will higher than the sire parent. Since such crossbreeding was aimed to incorporate the prolific genes into monotocus breed (Malpura) and ultimately to increase the lambing rate per time through incidences of multiple births. Hence, it become necessary to analyse G×M lambs in terms of attainment of body weight vis-à-vis their counterpart Malpura lambs so that further breeding and selection strategy could be formulated. The least squares means of body weights at different ages and growth rate in different periods in Malpura lambs are presented in Table 1 and 2. The corresponding results in G×M lambs are depicted in Table 3 and 4. The least squares means for birth 3, 6 and 12 month body weights in Malpura were 2.97, 12.35, 19.28 and 27.90 kg respectively. Maximum average daily gain (ADG) was obtained during 0-3 month age (103.9 g) followed by 3-6 month and 6-12 month period of age because dam component plays a major role during pre-weaning stage of lamb and after that lamb gained according to its capability in prevailing management and environmental conditions. Sex of the lamb, year of birth and ewes weight at lambing influenced significantly all the body weights and ADG of the Malpura lambs. The lambs could not perform well in the year 1998 as did in other years due to occurrence of Enterotoxaemia (ET).

Table 3. Least squares means for body weights (kg) in Garole×Malpura lambs

Particulars	Body weights at			
	Birth	3 month	6 month	12 month
Overall	2.11±0.04 (230)	10.25±0.30 (211)	15.34±0.35 (204)	21.82±0.51 (121)
Sex	NS	**	**	**
Male	2.16±0.05 (114)	10.86±0.32 (105)	16.84±0.38 (100)	23.73±0.60 (46)
Female	2.07±0.05 (116)	9.63±0.34 (106)	13.83±0.42 (104)	19.91±0.55 (75)
Year	NS	**	**	**
1998	2.15±0.08 (46)	9.31±0.49 (44)	12.86±0.56 (43)	20.11±0.77 (27)
1999	2.19±0.07 (44)	10.71±0.43 (41)	15.97±0.54 (40)	21.05±0.70 (27)
2000	2.00±0.07 (33)	11.23±0.44 (30)	17.23±0.60 (30)	23.46±0.77 (21)
2001	2.12±0.04 (107)	9.74±0.26 (96)	15.28±0.34 (91)	22.67±0.55 (46)
Dam breed	NS	NS	**	NS
Malpura	2.07±0.05 (179)	9.68±0.30 (169)	16.14±0.41 (164)	21.96±0.56 (104)
G×M	2.16±0.08 (51)	10.81±0.53 (42)	14.53±0.50 (40)	21.68±0.74 (17)
Type of birth	**	**	NS	NS
Single	2.40±0.04 (192)	10.98±0.27 (181)	15.76±0.32 (176)	21.78±0.43 (110)
Twins	1.83±0.07 (38)	9.51±0.48 (30)	14.91±0.62 (28)	21.86±0.92 (11)
Regression ewe's weight	**	**		
	0.042±0.007	0.181±0.047	-	-

** $p<0.01$; NS, Non-significant; Within parentheses are number of observations.

Table 4. Least squares means for average daily gain (g) in G×M lambs

Particulars	Average daily gain (ADG)		
	0-3 month	3-6 month	6-12 month
Overall	90.15±3.11 (211)	62.36±2.19 (204)	26.56±1.82 (121)
Sex	**	**	NS
Male	96.38±3.39 (105)	72.27±2.44 (100)	25.61±2.16 (46)
Female	83.92±3.54 (106)	52.45±2.65 (104)	27.51±1.97 (75)
Year	**	**	*
1998	79.28±5.12 (44)	49.63±3.54 (43)	29.20±2.75 (27)
1999	94.41±4.55 (41)	66.30±3.43 (40)	21.42±2.50 (27)
2000	102.53±4.65 (30)	69.82±3.81 (30)	27.88±2.74 (21)
2001	84.38±2.72 (96)	63.70±2.15 (91)	27.74±1.97 (46)
Dam breed	NS	**	NS
Malpura	84.09±3.19 (169)	67.81±2.61 (164)	25.53±2.01 (104)
G×M	96.21±5.60 (42)	56.91±3.15 (40)	27.59±2.65 (17)
Type of birth	NS	NS	NS
Single	95.38±2.85 (181)	58.54±2.01 (176)	25.24±1.54 (110)
Multiple	84.93±5.04 (30)	66.19±3.95 (28)	27.88±3.27 (11)
Regression of ewe weight	**		
	1.52±0.49	-	-

* p<0.05; ** p<0.01; NS. Non-significant. Within parentheses are number of observations.

Differences due to year of births were attributable to variations in environmental conditions and availability of other inputs. Similar results have also been reported in Malpura and Avikalin sheep (Arora et al., 1999; Sharma et al., 1999b). In G×M genotype, sex of lamb and year of birth significantly affected all the body weights barring birth weight (Table 3). Type of birth also affected significantly birth and weaning weight only and not the later body weights, which indicated that the lamb born as twins compensated their live weight gain at age of six month and yearling stage. The yearling weight of twin born lambs was almost at par with the single born lambs. It is evident from the fact that the type of birth did not influence ADG for different periods i.e. 0-3, 3-6 and 6-12 month age groups.

However, little bit more ADG during 3-6 and 6-12 month period was observed in lambs born as twins. Ewes weight at lambing significantly influenced the birth and weaning weight of lambs of both the genotypes indicated that due care of dams is required during pregnancy to obtain the healthy lamb crop. Simultaneously, it has influenced the pre-weaning growth rate of the lambs. Dam breed of the lambs did not affect the body weights significantly except 6 month body weight. Garole×Malpura lambs born out from Malpura dams (mature weight 24-25 kg) were not statistically different from that G×M lambs born out from G×M ewes (mature weight 22-23 kg) because the body size of G×M ewes was not markedly lower than the Malpura ewes. Similar to Malpura lambs, in G×M lambs also maximum ADG was obtained during pre-weaning stage (90.2 g) followed by 3-6 (62.4 g) and 6-12 month age group (25.6 g). Year of birth significantly influenced all the body weights and ADG which might be because of variation in availability of inputs (feeding stuffs) and other environmental conditions. Maximum ADG was observed in the year 2000 and lower being in 1998 due to occurrence of ET in lambs. Males significantly registered higher growth rate during 0-3 and 3-6 month age group compared to their counterpart female lambs. Dam breed of the lambs influenced only 3-6 month period ADG because G×M born out from Malpura ewes weighed significantly higher at 6 months of age compared to G×M lambs belonging to G×M ewes. Results of body weights in Malpura and Garole× Malpura lambs (Tables 1 and 3) revealed that Malpura lambs exhibited 40.75, 20.50, 20.40 and 21.80% superiority over their counterparts G×M lambs with respect to birth, 3, 6 and 12 month weight. The overall least squares means for birth, 3, 6 and 12 month body weights in G×M lambs were 2.11, 10.25, 15.34 and 21.82 kg, respectively (Table 3). The difference in Malpura and G×M in birth weight was more than 40% and it became just half in subsequent stages, which indicated that Garole×Malpura lambs including twins compensated their body weights at weaning stage considerably and maintained this tendency till yearling stage. Significantly lower body weights and growth rate of lambs sired by Garole rams with Deccani/Bannur as dam breed compared to the lambs sired by Deccani and Bannur rams with Deccani/Bannur as dam breed have also been reported by Nimbkar et al. (2000; 2003a). In India, no genuine research work towards incorporating the fecundity genes into monotocus native sheep breeds for increasing their reproductive efficiency through introduction of prolific native Garole has been carried out. However, during last 7-8 years, a systematic work on Garole and its crossbreeding

Table 5. Ewe productivity efficiency in Malpura and Garole× Malpura ewes

Year	kg weaned per ewe lambed	
	Malpura	Garole×Malpura
1998	9.54 (144)	-
1999	12.64 (155)	-
2000	13.25 (115)	10.19 (11)
2001	12.46 (150)	11.51 (28)
Overall	11.86 (564)	11.07 (39)

Within parentheses are number of available weaners.

with other native breed (Malpura sheep) has been initiated at Central Sheep and Wool Research Institute, Avikanagar on large scale and at Nimbkar Agriculture Research Institute, Phalton, Maharastra on limited numbers. Therefore, negligible literature is available on these aspects to support or contradict the present findings.

Ewe productivity efficiency

The ewe productivity efficiency in terms of kg weaned per ewe lambed or weaning efficiency (W.E.) of the ewe is an extremely important characteristic of economic mutton production programme because it covers two important factors: 1. Mortality of the lambs up to weaning stage (90 days). 2. Weaning weight of available lambs. Therefore, to improve the W.E. of the ewe due care has to be given to both the factors because if the contribution of the either factor or both is low then automatically weaning efficiency will be affected adversely. The weaning efficiency of G×M ewes was compared with Malpura ewes (Table 5). The overall kg weaned per ewe lamb in Malpura sheep was 11.86 kg and in G×M sheep it was 11.07 kg. The weaning efficiency of Malpura ewes ranged from 9.54 (1998) to 13.25 kg (2000). There was little variation among all the years except 1998 because in that year there was occurrence of ET in the lambs which leads to mortality and poor performance of the lambs. The weaning efficiency of G×M ewes improved by more than one kg in a period of one year, however, data are based on small numbers. Results obtained in respect of growth performance of the lambs and weaning efficiency of both the genetic groups indicated that Malpura inheritance would have to increase up to 75% level for enhancing the growth of crossbred lambs from existing status but presence of prolific gene(s) needs to be ensured in that condition. In addition, by improving the management one may expect harvesting better returns from G×M genetic group so that advantage of multiple births obtained in this group is realised through ewe productivity efficiency (kg. lambs weaned per ewe lambed).

Reproductive performance

Results on reproductive efficiency obtained in case of Malpura and G×M ewes are depicted in Table 6. The reproduction results in respect of G×M are compiled from the base year i.e. 2000 from where reproduction traits started to observe on G×M ewes. Lambing rate on ewes available basis which determine the flock reproductive efficiency as a whole and also covering unrecognised embryo/foetus losses i.e. it is measured in terms of live lambs born out of available ewes in the flock in a specified period. It averaged 89.47 and 118.60% in Malpura and G× M ewes, respectively. The average litter size at birth and weaning was 1.02 and 0.97 in Malpura ewes whereas in G×M ewes it was 1.46 and 1.19, respectively. The pooled

Table 6. Reproductive performance of Malpura and Garole×Malpura ewes

Year	Lambing rate (%)		Litter size at				Twinning (%)	
			Birth		Weaning			
	M	G×M	M	G×M	M	G×M	M	G×M
1998	89.67	-	1.01	-	0.89	-	1.23	-
1999	96.43	-	1.04	-	0.99	-	3.85	-
2000	80.54	106.66	1.00	1.33	0.98	1.08	0.84	33.00
2001	90.17	125.00	1.04	1.52	1.0	1.30	4.00	52.17
Pooled	89.47	118.60	1.02	1.46	0.97	1.19	2.55	45.71

Table 7. Survivability pattern in Malpura and Garole×Malpura sheep (%)

Year	Malpura			Garole×Malpura		
	0-3 month	3-12 month	Adults	0-3 month	3-12 month	Adults
1998-99	95.96	90.53	92.49	97.53	81.82	96.30
	(297)	(169)	(429)	(81)	(44)	(27)
1999-02	97.94	90.30	93.91	95.00	95.24	96.00
	(289)	(165)	(411)	(80)	(42)	(50)
2000-01	98.27	95.27	95.81	93.80	97.44	97.30
	(289)	(169)	(453)	(145)	(39)	(74)
2001-02	98.09	95.51	95.82	97.58	91.51	95.69
	(315)	(178)	(479)	(207)	(106)	(116)

Within parentheses are number of observations.

twin lambing percentage in G×M ewes on the basis of 35 lambing obtained so far was 45.71% whereas in Malpura ewes it was 2.55%. Drastic increase in twinning percentage and in other reproductive traits was observed in G×M ewes compared to Malpura and interestingly an increasing trend in these traits was also noticed in a period of one year (Table 6). These results are evident of the fact that prolific genes have been incorporated into the Garole crosses and needs further exploitation through appropriate selection and breeding strategy. However, these results are based on small numbers and need further research to reach to definite conclusions with regard to net returns from such crosses. Negligible systematic research work on increasing reproductive rate of monotocus breeds of sheep and efficiency of lamb production by crossing them with prolific breed of sheep has been carried out in India. On limited scale, Nimbkar Agricultural Research Institute, Phalton (Maharashtra) has initiated the crossbreeding programs of Garole with Deccani/Bannur/Pattanwadi and Garole crosses were reported to have the genetic potential for high reproductive efficiency (Nimbkar et al., 1998; 2000; 2003b).

Survivability

Survivability is a very crucial factor in deciding the economic viability of any breed improvement programme. It is the indicator of adaptability of a genetic group under prevailing climatic and management conditions of a particular region. The results obtained revealed that G×M genotype has almost similar survivability as observed in case of Malpura sheep during the four years included in the study (Table 7). These results further indicated that the crossbred progenies are having genes of adaptation from Malpura sheep and the prolific genes from Garole. In fact, the survivability of Garole being the native of hot humid coastal belt of southern West Bengal was poor under semi-arid region (Sharma et al., 2001).

CONCLUSIONS

Results indicated that the fecundity genes have been incorporated and this genetic group is adaptable under semi-arid tropical tract of the country. There is a need to further strengthen the G×M half-breds and the ewes of this genetic group required to be backcrossed with Malpura rams for minimizing the differences in the body weights of these genetic groups. Simultaneously it has to be ensured that incorporated prolific genes do not get lost. Garole inheritance would have to be stabilized towards evolving new prolific strain of sheep having optimum body weight for enhancing the mutton production in the country. Scope does exist to harvest better returns through enhancing "Ewe productivity efficiency" by improving management practices for this newly evolved (G×M) genetic group.

ACKNOWLEDGEMENTS

Authors are grateful to Shri A.K. Prasad, T-II-3 and Dr. O. P. Koli, T-7 Division of Animal Genetics and Breeding for checking of data listing and typing the manuscript meticulously.

REFERENCES

Arora, A. L., R. C. Sharma, H. K. Narula and Ravindra Kumar. 1999. Comparative performance of Avikalin and Malpura sheep. Indian J. Small Rumin 5:4-8.

Davis, G. H., S. M. Galloway, I. K. Ross, S. Gregan, J. Ward, B. V. Nimbkar, P. M. Ghalsasi., C. Nimbkar, G. D. Gray, Subandriyo, I. Inounu, B. Tiesnamurti, E. Martynuik, E. Eythorsdottir, P. Mulsant, F. Lecerg, J. P. Hanrahan, G. E. Bradford and T. Wilson. 2002. DNA test in prolific sheep from eight countries provide new evidence on origin of the Booroola (*Fec B*) mutation. Biology of Rep. 66:1869-1874.

Ghalsasi, P. M. and B. V. Nimbkar. 1993. The "Garole" Microsheep of Bengal, India. Anim. Genet. Reso. Inform. 12:73-79.

Harvey, W. R. 1975. Least-squares analysis of data with unequal subclass numbers. USDA, ARS, H-4, Washington DC, p. 157.

Nimbkar, C., P. M. Ghalsasi, R. R. Ghatge and G. D. Gray. 1998. Establishment of prolific Garole sheep from West Bengal in the semi-arid Deccan plateau of Maharastra. In: Proceedings of 6th World Cong. Genet. Appl. Lives. Prod., Armidale. pp. 257-260.

Nimbkar, C., P. M. Ghalsasi, S. W. Walkden-Brown, L. P. Kahn and G. D. Gray. 2000. A comparison of the growth performance and worm resistance of lambs produced by diallel crossing of three Indian sheep breeds. Asian-Aust. J. Anim. Sci. 13:72-75.

Nimbkar, C., P. M. Ghalsasi, A. Swan, S. W. Walkden-Brown and L. P. Kahn. 2003a. Evaluation of growth rates and worm resistance of Deccani and Bannur lambs and their crosses with Garole. Anim. Sci. 503-515.

Nimbkar, C., P. M. Ghalsasi, J. F. Maddox, V. C. Pardeshi, M. N. Sainani, V. Gupta and S. W. Walkden-Brown. 2003b. Expression of the *Fec B* gene in Garole and crossbred ewes in Maharashtra, India. In: Proceeding of the Assoc. for Adv. Anim. Breed Genet. 15:111-114.

Sharma, R. C., A. L. Arora, H. K. Narula and R. N. Singh. 1999a. Characteristics of Garole sheep in India. Anim. Genet. Reso. Inform. 26:57-64.

Sharma, R. C., A. L. Arora, R. Kumar and H. K. Narula. 1999b. Impact of genetic and non-genetic factors on growth profile in Malpura and Avikalin lambs. Indian J. Anim. Sci. 69:820-822.

Sharma, R. C., A. L. Arora and B. U. Khan. 2001. Garole: A Prolific sheep of India. Central Sheep and Wool Research Institute, Avikanagar-304501, Rajasthan, India. Research Bulletin, p. 17.

Turner, H. N. 1982. Origins of the CSIRO Booroola. In: The Booroola Merino (Ed. L. R. Piper, B. M. Bindon and R. D. Nethery). CSIRO, Australia. pp. 1-7.