Comparison of Sumatra sheep and hair sheep crossbreds. III. Reproductive performance of F2 ewes and weights of lambs

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Abstract

This experiment, conducted in the humid lowland tropics of North Sumatra, Indonesia involved 132 young Sumatra (S); Virgin Island × Sumatra (HC); and Barbados Blackbelly × Sumatra (BC) ewes. The ewes were mated with rams of their same genotype and monitored until each ewe had weaned two crops of lambs. Data from 230 lambings and 350 lambs were included in the analysis. Mean ages at first and second lambing were 465 ± 3 and 694 ± 6 days, respectively. Mean interval between first and second lambings was 231 ± 5 days. Mean litter size averaged 1.52 ± 0.04 at birth and 1.23 ± 0.04 at weaning. There were no significant effects of genotype on age at lambing, lambing interval or litter size. Overall mean weights of lambs at birth and weaning were 1.81 ± 0.02 and 9.5 ± 0.1 kg. Genotype, type of birth and rearing, and sex of lamb affected lamb weights at birth and weaning. S lambs were the smallest (1.3 and 6.9 kg at birth and weaning). HC (1.8 and 9.6 kg) and BC (2.0 and 10.3 kg) were significantly heavier (p < 0.01) at both birth and weaning. Overall pre-weaning mortality was 18.9%. Mortality was 3.1% for single lambs, 19.6% for twins and 54.7% for triplets and quadruplets. Dam productivity index (DPI) was affected by genotype (p < 0.001) and averaged 13.2 ± 1.0 kg for S, 19.4 ± 1.0 kg for HC and 21.3 ± 1.0 kg for BC. Ewe weight at second lambing was influenced (p < 0.01) by genotype, averaging 21.2 ± 0.5 kg for S, 26.8 ± 0.5 kg for HC and 29.0 ± 0.5 kg for BC. In terms of DPI, the superiority of BC ewes over S ewes was 61%, and the superiority of HC ewes was 47%. Reproductive performance of the F2 ewes was excellent, but lamb weights and lamb mortality were less than optimum. The superiority of the crossbreds was maintained into the F2 generation of ewes producing F3 lambs, despite sub-optimal nutrition. Crossing the native Sumatra sheep with the two Caribbean breeds resulted in an increase in mature size and growth rate, while viability and reproductive performance of the crosses were fully equal to those of the native breed.

Keywords: Sumatra; Barbados Blackbelly; Virgin Island; Hair sheep; Reproductive rate; Heterosis retention

1. Introduction

An experiment was started in 1991 to compare native coarse-wooled Sumatra sheep and crosses with three breeds of hair sheep. Previous results (Gatenby et al., 1997a) have shown that F1 crossbred Barbados Blackbelly and Virgin Island lambs grew considerably faster than the purebred Sumatra and crossbred Java Fat-tail lambs. Also Gatenby et al. (1997b) reported that the total weight of lamb weaned by F1 Barbados Blackbelly and Virgin Island crossbred ewes was
greater than that of purebred native Sumatra ewes and Java Fat-tail crossbred ewes. The increase in productivity of the hair sheep crossbreds arose largely from heavier lambs; reproductive rates (i.e. age at lambing, lambing interval, litter size and lamb mortality) were similar for all genotypes. Feeding trials (Merkel et al., 1999) have shown that the hair sheep crossbred lambs have a higher growth potential than native Sumatra sheep, and can contribute to increased sheep meat production in Indonesia.

This paper reports the reproductive performance and birth and weaning weights of lambs of a randomly-selected sample of F2 Barbados Blackbelly×Sumatra and Virgin Island×Sumatra crosses and purebred native Sumatra ewes.

2. Materials and method

2.1. Animals and mating program

This phase of the experiment was conducted at the AARD Research Station for Animal Production in Sei Putih, North Sumatra, Indonesia from 1994 through 1997. This station is located in the humid lowland tropics (average minimum temperature 23°C, average maximum temperature 32°C, annual rainfall 1800 mm).

The genotypes involved were Sumatra (S, n=42), Virgin Island (also known as St Croix)×Sumatra (HC, n=47), and Barbados Blackbelly×Sumatra (BC, n=43). At the beginning of the study there was a total of 132 young ewes. These ewes were born between June 1993 and July 1994. All were first exposed to the ram at ≈10 months of age.

Ewes were exposed to fertile rams during 34-day mating seasons, four times a year. Natural services were individually supervised following twice-daily detection of oestrus by vasectomised rams. Ewes in each group were mated with rams of their same genotype, so the resulting lambs in the two crossbred groups were F3s and there was a control group of S lambs. The numbers of BC, HC and S rams used were 6, 8 and 5, respectively. Rams were randomly allocated to ewes with the restriction that sib matings were avoided.

Ewes and their lambs were monitored until each ewe had weaned two crops of lambs or was no longer in the flock. Of the initial 132 ewes, a total of 104 (79%) were present at the end of the experiment. Eight HC ewes were moved to a farmers’ multiplication unit after their first litter was weaned. All these animals successfully reared their second litters so, in total, 85% of ewes produced two litters. However, the data on lamb weights for the eight transferred ewes were not included in the analysis as conditions were not identical with those on the research station. Eighteen ewes died or were culled because they were barren or chronically ill, and two ewes were stolen. Chi-square tests showed no significant differences among genotypes in these proportions. Data from a total of 230 lambings and 350 lambs were included in the analysis.

2.2. Management and feeding

Ewes and suckling lambs were allowed to graze in a rubber plantation during the day from 08:00 h to 16:00 h, and were housed at night. The forage in the grazing areas was unimproved and comprised mainly Ottochloa nodusa, Paspalum conjugatum, Axonopus compressus and Mikania cordata. Ewes were managed in mixed groups of all genotypes and treated identically. Ewes nursing twins, triplets or quadruplets were fed concentrate supplement at a nominal rate of 250 g per day per head. Ewes nursing single lambs were given concentrate for only the first two weeks after lambing. Lambs were weaned at exactly 3 months of age. From 3 to 6 months of age lambs were stall-fed with grass (cut from an ungrazed part of the plantation, plus cultivated Brachiaria spp.) and 300 g per day per head concentrate. From 6 months of age when the ewe lambs joined the main ewe flock for grazing, and until 15 months of age, they were fed 200 g per day concentrate. The concentrate composition was 25% rice bran, 25% cassava meal, 25.8% palm kernel cake, 20.7% molasses, 1.4% fish meal, 1.1% lime and 1.0% minerals. All animals in the grazing flock were given anthelmintic every 3 months and moved to a new grazing area. There were no other routine veterinary interventions.

2.3. Data collection and analysis

Each animal was individually identified. Records included date of mating, date of lambing, litter size, birth weights and weaning weights. A dam productivity
index (DPI) was calculated for each ewe which lambed twice. This is defined as

\[
\text{DPI} = \frac{\text{Total weight (kg) of lambs weaned at 1st and 2nd lambings}}{\text{Age of ewe (days) at 2nd lambing} - 200 \text{ days}}
\]

Data on age of ewe, lambing interval, litter size, lamb weights, dam productivity and ewe weight were analysed using the GLM procedure and lamb mortality was analysed using the CATMOD procedure (SAS, 1988).

Age of ewe at lambing, lambing interval, DPI and ewe weight were analyzed by least squares analysis of variance to examine the effect of genotype. The model for litter size included genotype and parity of ewe. The model for lamb birth weight included genotype, type of birth, sex of lamb, parity of ewe and sire within breed. The model for weaning weight was similar, but type of birth and rearing replaced type of birth. The model for lamb mortality included genotype, type of birth, sex of lamb and parity of ewe. A second analysis of age of ewe at second lambing and lambing interval included type of rearing of the first litter in addition to genotype and group of ewe.

Preliminary analyses including interaction terms indicated that none was significant, so in the final models interactions were excluded. All components of the models were considered fixed effects, except sire within breed, which was considered as a random effect.

### 3. Results

**3.1. Age of ewes at lambing**

The age of ewes at first lambing ranged from 428 to 716 days, and at second lambing from 625 to 840 days (Table 1). Genotype had no significant effect on these traits. Likewise no significant effect of first litter size on age at second lambing was observed.

**3.2. Lambing interval**

Table 1 shows that the mean interval between first and second lambings was 231±5 days. There were no significant effects of genotype on lambing interval. There were no significant effects of litter size at first lambing on subsequent lambing interval.

**3.3. Litter size**

Litter size ranged from 1 to 4 lambs at birth and from 1 to 2 lambs at weaning. Mean litter size

<table>
<thead>
<tr>
<th>Genotype</th>
<th>n</th>
<th>Age at first lambing (days)</th>
<th>Genotype</th>
<th>n</th>
<th>Age at second lambing (days)</th>
<th>Genotype</th>
<th>n</th>
<th>Lambing interval (days)</th>
</tr>
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<tbody>
<tr>
<td>Overall</td>
<td>126</td>
<td>428–716</td>
<td>Overall</td>
<td>104</td>
<td>625–840</td>
<td>Overall</td>
<td>104</td>
<td>175–385</td>
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<td>Range</td>
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<td>Median</td>
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<tr>
<td>Mean±SE</td>
<td></td>
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<td>Mean±SE</td>
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<td></td>
<td>Mean±SE</td>
<td></td>
<td></td>
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<tr>
<td>BC(^a)</td>
<td>41</td>
<td>457±6</td>
<td>NS(^d)</td>
<td></td>
<td></td>
<td>NS</td>
<td></td>
<td>233±8</td>
</tr>
<tr>
<td>HC(^b)</td>
<td>45</td>
<td>468±6</td>
<td>NS</td>
<td></td>
<td></td>
<td>NS</td>
<td></td>
<td>227±9</td>
</tr>
<tr>
<td>S(^c)</td>
<td>40</td>
<td>469±6</td>
<td>NS</td>
<td></td>
<td></td>
<td>NS</td>
<td></td>
<td>232±9</td>
</tr>
</tbody>
</table>

\(^a\) Barbados Blackbelly×Sumatra.
\(^b\) Virgin Island×Sumatra.
\(^c\) Sumatra.
\(^d\) \(p>0.05\).
averaged 1.52 at birth and 1.23 at weaning (Table 2). There were no significant effects of genotype or parity of ewe on litter size.

3.4. Weight of lambs

Analysis of factors affecting lamb weights (Table 3) showed that genotype, type of birth and rearing, and sex of lamb affected \( p<0.01 \) lamb weights at birth and weaning. Parity of ewe affected birth weight \( p<0.001 \) but not weaning weight, and sire within breed had no significant effect on these traits. S lambs were the lightest (1.3 and 6.9 kg at birth and weaning). HC (1.8 and 9.6 kg) and BC (2.0 and 10.3 kg) were significantly heavier at birth and weaning than S lambs.

3.5. Mortality of lambs

Overall mortality was 18.9\% (Table 3). Type of birth and parity of ewe affected mortality \( p<0.001 \), but genotype and sex of lamb did not. Mortality increased substantially with litter size; it was 3.1\% for single lambs, 19.6\% for twins and 54.7\% for triplets and quadruplets. Mortality in the first and second litters was 12.4 and 26.1\%, respectively.

3.6. Dam productivity index and weight of ewes

Overall mean DPI was 18.0±0.6 kg (Table 2). The HC and BC were significantly \( p<0.001 \) more productive than S ewes. HC and BC crossbred ewes were significantly \( p<0.01 \) heavier at second lambing than purebred S ewes. The ratio of (DPI/ewe weight) for the S, HC and BC ewes, respectively, was 0.62, 0.72 and 0.73, showing that on a unit body weight basis, the crossbred genotypes were superior to the native ewes.

4. Discussion

4.1. Breed differences

The F2 hair sheep crossbred ewes (BC and HC) were more productive than purebred native S ewes (S). In terms of DPI, the superiority of BC ewes over S ewes was 61\%, and the superiority of HC ewes was 47\%. As in the F1 ewes, the increase in productivity of the F2 crossbreds arose largely from heavier lambs; reproductive characteristics (age at lambing, lambing interval, litter size and lamb mortality) were similar for all genotypes.

Some of the superiority of the crossbred groups could be due to heterosis, but the amount of heterosis could not be quantified in this experiment because we did not have purebreds of the two introduced breeds. Two aspects of this and previous studies (Gatenby et al., 1997a, b) indicate that heterosis was probably not very important. First, reproduction traits, which usually show the highest heterosis, differed little between purebred and crossbred groups, while there were large differences in growth traits, which gener-
ally show less heterosis than reproductive traits. Secondly, the difference between the crossbreds and the pure S group was similar for F2 and F1 lambs (Gatenby et al., 1997a) and for F2 ewes with F3 lambs and F1 ewes with F2 lambs (present study and Gatenby et al., 1997b). The expectation, if heterosis is due to dominant genes, is that half the F1 heterosis will be lost in the F2. The consistent crossbred–purebred difference over generations is more readily explained by additive differences in merit of the breeds than by heterosis.

The effects of crossing with the Barbados Blackbelly and Virgin Island breeds appear to be due to introduction of genes for greater mature size and more rapid growth. These do not necessarily increase biological efficiency of production, although the ratio of weight of lamb per ewe to estimated ewe maintenance costs indicate that the biological efficiency of the F1 crossbred ewes was substantially higher than that of the S ewes (Gatenby et al., 1997b). If costs of production are fixed, i.e. per head, an increase in size, with no change in reproduction, will result in an increase in economic efficiency. Also, since the native Sumatra sheep is one of the smallest breeds (mature ewe weight ≈21 kg), an increase in size may increase acceptability of carcasses, at least for urban or international markets.

The maintenance of superiority in the F2 ewes and F3 lambs is particularly noteworthy. The results of many trials with crossbred dairy cattle in the tropics, reviewed by Cunningham and Syrstad (1987) and

| Table 3 | Least squares means for the effects of genotype, type of birth, sex of lamb and parity of ewe on weights of lambs at birth and weaning, and pre-weaning mortality |
|---|---|---|---|
| Lamb weights (kg) | At birth | At weaning | Pre-weaning lamb mortality (%) |
| | n | Mean±SE | n | Mean±SE | n | Mean |
| Overall | 350 | 1.81±0.02 | 284 | 9.5±0.1 | 350 | 18.9 |
| Genotype | | | | | | |
| Bc“ | 116 | 1.97±0.04 | 101 | 10.3±0.2 | 116 | 12.9 |
| HC“ | 119 | 1.82±0.04 | 94 | 9.6±0.2 | 119 | 21.0 |
| S“ | 115 | 1.33±0.04 | 89 | 6.9±0.2 | 115 | 22.6 |
| Type of birth (or birth and rearing) | | | | | | |
| 1 (1) | 129 | 2.24±0.03 | 125 | 11.0±0.2 | 129 | 3.1b |
| (21) | 19 | 8.8±0.4 | 118 | 8.1±0.2 | 168 | 19.6d |
| 2 (22) | 168 | 1.70±0.03 | 22 | 7.8±0.4 | 53 | 54.7p |
| 3 (32) | 53 | 1.19±0.05 | 22 | 7.8±0.4 | 53 | 54.7p |
| Sex of lamb | ** | ** | NS | ** | ** | ** |
| Male | 170 | 1.77±0.03 | 137 | 9.2±0.2 | 170 | 19.4 |
| Female | 180 | 1.65±0.03 | 147 | 8.6±0.2 | 180 | 18.3 |
| Parity of ewe | *** | NS | *** | NS | NS | NS |
| First | 185 | 1.59±0.03 | 162 | 9.2±0.2 | 185 | 12.4h |
| Second | 165 | 1.83±0.03 | 122 | 8.6±0.2 | 165 | 26.1i |
| Sire (within breed) | NS | NS | ** | ** | ** | ** |

a Barbados Blackbelly×Sumatra.  
b Virgin Island×Sumatra.  
c Sumatra.  
d Single lamb reared as single.  
e Twin lamb reared as single.  
f Twin lamb reared as twin.  
g Triplet or quadruplet reared as twin.  
h,i,j Within each comparison, means with the same superscript are not significantly different (p>0.05).  
k p>0.05.  
** p<0.01; *** p<0.001.
Rege (1998), show that the superiority of F₁ \textit{Bos taurus}×\textit{Bos indicus} crosses is greatly reduced in the F₂. In fact, the loss of heterosis appears to be nearly 100%, and not 50% as expected. This strongly suggests favourable epistatic combinations in the two parental types which are lost in the F₂.

There have been relatively few reports on retention of heterosis in sheep crossbreeding, with the data available coming from studies of temperate breeds (Young et al., 1986). There appears to be little information available on heterosis retention in crossbred tropical sheep. The results presented here do not provide a quantitative estimate of heterosis for reproductive and growth traits, but indicate that (a) heterosis effects in crosses of tropical breeds of sheep are not large, and (b) the decline in heterosis from F₁ to F₂ found consistently in dairy cattle crossbreeding studies in the tropics, does not occur in crosses of tropical sheep breeds. The most probable explanation for these differences between cattle and sheep is that, in the present experiment, only tropical breeds were involved, while in the dairy cattle studies crosses of temperate and tropical breeds were carried out. In fact, the two types of cattle are classified as different species, and although that classification has been debated, the crossbreeding results appear to support it.

The fact that the imported breeds used to produce crossbreds in this study evolved in tropical environments is most likely an important factor in the similarity in reproductive performance of the crossbred and native sheep.

4.2. Level of management

Contrary to what is observed in most flocks, weaning weights and pre-weaning mortality of lambs born to second parity ewes were not as good as those of first parity lambs. From 1995 to 1997 the ewes were subjected to some stress due to an erratic supply of concentrate and were in less than optimum body condition. This is most easily demonstrated by comparing the weaning weights of purebred S lambs and the pre-weaning mortality of all genotypes of the F₂ and F₃ generations: F₂ lambs born 1993–1994, 8.5±0.2 kg and 11.7% (Gatenby et al., 1997b); and F₃ lambs born 1995–1997, 6.9±0.2 kg and 18.9%.

It might have been expected that the superiority of the crossbred ewes would be reduced when conditions are harsh, for example at second parity in this study, when nutrition was apparently less adequate. The crossbred ewes are larger than the native ewes and so would be expected to need more food to express their higher production potential. Genotype-by-parity interactions for all traits were not significant, indicating that the crossbred ewes retain their superiority over the native Sumatra ewes even when nutritional conditions are not ideal.

5. Conclusion

The superiority of the hair sheep crossbreds was maintained into the F₂ generation of ewes producing F₃ lambs and, despite the less than optimum nutritional conditions prevailing in the flock, the crossbred ewes maintained their superiority in total lamb production over the local Sumatra sheep. Crossing with the two Caribbean breeds resulted in an increase in mature size and growth rate, while viability and reproductive performance of the crosses were fully equal to those of the native breed.

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