Contributed paper

AN EVALUATION OF THE EFFECT OF THE BOOROOLA GENE, FEC B, ON PRODUCTIVITY IN A BORDER LEICESTER X MERINO PRIME LAMB PRODUCTION SYSTEM

L.R. Piper[1], A.A. Swan[2], J.M. Elsen[3], L. Bodin[3], H.G. Brewer[1] and B.M. Bindon[1]

[1]CSIRO Agriculture and Food, F D McMaster Laboratory, Armidale, NSW 2350,
[2]Animal Genetics and Breeding Unit, University of New England, Armidale, NSW 2351,
[3]INRAe, GenPhySe, 31326 Castanet-Tolosan, France

SUMMARY

The direct effect of the Booroola gene, Fec B, on ewe reproduction rates and ewe productivity traits has been evaluated in a typical Border Leicester x Merino prime lamb production system. The ovulation rate and prolificacy of the Border Leicester x Booroola Fec B^{b+} ewes were significantly higher than those of traditional Border Leicester x Merino ewes. This advantage was offset by significantly lower lamb rearing ability with the result that there was no advantage in terms of lambs weaned/ewe joined or in \$ returned/ewe joined. Targeted supplementary management strategies (ultra-sound scanning, supplementary feeding) appear to show promise in realising the gains from the increased prolificacy.

INTRODUCTION

In a previous report (Bindon and Piper 1990), the role of the Booroola Merino in the Australian prime lamb industry was evaluated in a series of experiments conducted at the Armidale, NSW, CSIRO research stations, Longford and Arding during the period 1982-1992. Bindon and Piper (1990) reported results from a seven-year period (1982-1988) of a typical autumn joining system where Border Leicester x Booroola (BLxB) or Border Leicester x Merino (BLxM) ewes were joined with Suffolk, Polled Dorset or SIROMT (Bindon *et al.* 1984) rams. Over that period, (Bindon and Piper 1990, Table 7), the BLxB ewes " had a 56% higher ovulation rate, a 43% higher prolificacy (lambs born per ewe lambing, LB/EL), a 22 % lower lamb survival (lambs weaned per lamb born, LW/LB) and a 15 % higher lambs weaned per ewe joined (LW/EJ) than the BLxM ewes, This resulted in an advantage of 7 % in revenue returned per ewe joined in favour of the BLxB ewes)".

In the Bindon and Piper (1990) study, the BLxB ewes were generated by crossing Border Leicester rams with Booroola Merino ewes maintained in an auxiliary flock independent of the main Booroola Merino breeding flock. This flock contained a mixture of the three Fec B genotypes (bb; b+; ++) and the resulting BLxB ewes were therefore also a mixture of Fec B genotypes (b+; ++). As a result, the effect of the Booroola gene, Fec B, on productivity in the Border Leicester x Merino prime lamb production system, was not clearly established.

This paper extends the scope of the original study by reporting new analyses on the estimated direct effect of the Booroola gene, Fec B, on ewe reproduction rate and productivity in a typical autumn joined Border Leicester x Merino prime lamb production system.

MATERIALS AND METHODS

Sheep. The ewes in this study were generated by joining Border Leicester rams with Booroola Merino or Control Merino ewes each year from 1976 to until 1990 except for 1981. The CSIRO Booroola Merino and the randomly bred Control Merino flocks have been described in detail elsewhere (Turner 1978; Piper and Bindon 1982). In all, 2243 records from 560-587 (depending on the trait being analysed) Border Leicester x ewes comprised the data analysed in this study. Over the period of the study (1982-1992) the ewes were joined with rams from the Suffolk, Poll Dorset or SIROMT (synthetic line derived from crosses of the Dorset Horn, Corriedale and Cheviot) breeds.

Traits Measured. For each of the ewes in each of the lambing years (1982-1992) the traits recorded were: Ovulation Rate (OR, assessed by laparoscopy), Fertility (ewes lambing/ewe joined, FERT), Prolificacy (or litter size, lambs born/ewe lambing, LS), Ewe Rearing Ability (lambs weaned/lamb born, ERA), Reproduction Rate (no. lambs weaned/ewe joined, NLW) and three ewe productivity traits, Lambs Sold/ewe joined (LSO/EJ), Lamb Weight Sold/ewe joined (LWS/EJ) and Revenue Returned/ewe joined ($ ret/EJ). The management of the ewe flocks and the reproduction rate and productivity traits observed have been described by Bindon *et al*. (1984).

S**tatistical Methods.** For the analyses to estimate ewe genotype at the Fec B locus, the lifetime prolificacy and ovulation rate records of the BLxB (B) ewes and of their Booroola Merino dams, were analysed using segregation analysis methodology developed by Elsen *et al.* (1988) and by Foulley and Elsen (1988). The software returns a probability that each of the B ewes is either b+ or ++. The data set analysed comprised 2243 records (1181 records from BLxC (C)) ewes and 1062 records from B (b+, ++) ewes with probabilities of being b+ (631 records) or ++ (431 records)) ranging between 0.9 and 1.

The reproduction traits were analysed using repeated record, mixed linear models adjusting for fixed effects using ASReml (Gilmour *et. al*. 2014). The model employed was:

$y \sim mu + \text{ewe type}_{i} + \text{ewe age}_{j} + \text{lambing year}_{k} + \text{sire breed of lamb}_{l} + \text{ewe}_{im} + \text{within ewe}_{imp}$

Ewe type (B b+, B ++, C) ewe age (2-7), lambing year (1982-1992) and Ram type (sire breed of lamb - Suffolk, Poll Dorset, SIROMT) were fitted as fixed effects while the between ewe effects (ewe_{im}) were fitted as random effects.

RESULTS

The means and standard errors (se) for the ewe reproduction and ewe productivity traits are given in Table 1. For the reproduction traits, and by comparison with the C ewes, the B ewes had 47% higher OR (P<0.001), 5% lower FERT (P=0.047), 35% higher LS (P<0.001), 16% lower ERA (P<0.001) and 2% lower NLW (n.s.). For the same reproduction traits, and by comparison with the ++ ewes, the b+ ewes had 100% higher OR (P<0.001), 11% lower FERT (P<0.001), 68% higher LS (P<0.001), 31% lower ERA (P<0.001) and 3% lower NLW (n.s.).

Table 1. Reproduction trait and ewe productivity trait means for the Border Leicester x Control (C), BorderLeicester x Booroola (B) and for the B++ and Bb+ ewes

Trait	No. ewes	C	B	++	b+
OR	584	2.09 ± 0.04	3.08 ± 0.04	2.04 ± 0.06	4.07 ± 0.05
FERT (EL/EJ)	587	0.82 ± 0.02	0.78 ± 0.02	0.83 ± 0.02	0.74 ± 0.02
LS (LB/EL)	560	1.72 ± 0.04	2.33 ± 0.04	1.74 ± 0.05	2.93 ± 0.05
ERA (LW/LB)	560	0.85 ± 0.02	0.71 ± 0.02	0.83 ± 0.02	0.57 ± 0.02
NLW (LW/EJ)	587	1.16 ± 0.05	1.14 ± 0.04	1.15 ± 0.06	1.12 ± 0.05
Lambs sold/EJ (LSO/EJ)	587	1.13 ± 0.05	1.09 ± 0.04	1.12 ± 0.06	1.06 ± 0.05
Lamb weight sold (LWS/EJ)	587	37.85 ± 1.49	35.51 ± 1.37	36.81 ± 1.97	33.17 ± 1.74
Revenue ($ ret/EJ)	587	22.2 ± 1.23	21.75 ± 0.87	23.1 ± 0.94	20.4 ± 1.09

For the Ewe productivity traits, and by comparison with the C ewes, the B ewes had 4% lower LSO/EJ (n.s.), 6% lower LWS/EJ (n.s.) and 2% lower $ ret/EJ (n.s.) For the same Ewe Productivity traits, and by comparison with the B++ ewes, the Bb+ ewes had 5% lower LSO/EJ (n.s.), 10% lower LWS/EJ (P=0.007) and 12% lower $ ret/EJ (P=0.011).

The analyses of variance for the ewe reproduction and productivity traits are given in Table 2.

Table 2. Probabilities from the Analyses of variance of the ewe reproduction and productivity traits.

Source	Mu	B v C	++ v b+	Lambing Year	Ewe Age	Ram Type
df	1	1	1	10	6	2
OR	<0.001	<0.001	<0.001	<0.001	<0.001	0.904
FERT (EL/EJ)	<0.001	0.047	<0.001	<0.001	0.002	<0.001
LS (LB/EL)	<0.001	<0.001	<0.001	0.015	<0.001	0.687
ERA (LW/LB)	<0.001	<0.001	<0.001	<0.001	0.059	0.627
NLW (LW/EJ)	<0.001	0.907	0.606	<0.001	<0.001	0.024
LSO (LSO/EJ)	<0.001	0.677	0.204	<0.001	<0.001	0.022
LWS (LWS/EJ)	<0.001	0.495	0.007	<0.001	<0.001	0.050
$ ret/EJ ($/EJ)	<0.001	0.704	0.011	<0.001	<0.001	0.118

For the fixed effects in the model, the differences between lambing years and between ewe ages were almost always significant. The effect of Ram Type varied and was not significant for OR, LS, ERA, or $ ret/EJ. There were significant differences between Ram Types for FERT (P<0.001), NLW (P=0.024), LSO (P=0.022) and for LWS (P=0.05).

DISCUSSION

At the time of this experiment, genotyping at the Fec B locus was not available because the causative mutation on the Bmpr1b gene was not discovered until about 10 years later (Souza *et al.* 2001; Wilson *et al.* 2001; Mulsant *et al.* 2001) and no blood samples were preserved. Utilisation of the segregation analysis software developed by Elsen *et al.* (1988) and Foulley and Elsen (1988) was therefore needed to estimate Fec B genotype, and to estimate the direct effect of the Fec B gene on reproduction rate and ewe productivity in a typical Border Leicester x Merino prime lamb production system.

The analyses reported above demonstrate that the increased ovulation rate and litter size of the B ewes is a direct effect of the Fec B gene. However, the lower fertility and ewe rearing ability of the B b+ ewes compared with the C ewes results in there being no advantage to the B ewes in NLW or any of the ewe productivity traits. These results agree with those of Southey *et al.* (2001) who reported that Merino–Rambouillet crossbred ewes introgressed with the Fec B allele do not produce more total weight of lamb at 30, 60 or 120 days postpartum than purebred Rambouillet ewes in spite of their higher reproductive performances.

These results contrast with those from Bindon *et al.* (1984) where the BLxB ewes had 21% higher NLW (LW/EJ) and 18% higher $ ret/EJ than the BLxC ewes. They also contrast with the results reported by Bindon and Piper (1990) where the BLxB ewes had 15% higher NLW (LW/EJ and 7% higher $ ret/EJ then the BLxC ewes. It is not clear why the results of the present analyses differ from those obtained from the smaller and earlier sub-sets of the data analysed by Bindon *et al.* (1984) and by Bindon and Piper (1990). These results also contrast with results from studies of the productivity of heterozygous Booroola Merino d'Arles ewes (MAb+) which is higher than that of the MA++ and pure-breed Merinos d'Arles (MA) under the pastoral management of the Merinos d'Arles breed in south-eastern France. The weight of 70-day lamb produced per ewe joined increased by 41% compared to non-carrier MA++ and MA, despite a lower lamb body weight at 70 days (Teyssier *et al.* 1998).

However, lower ERA is the main contributor to the lack of difference between the B and the C ewes in NLW, and a study by Hinch *et al.* (1996) demonstrates that ERA can be significantly improved (from 58% to 73%) by a combination of targeted supplementary feeding and pregnancy scanning strategies. These results suggest that optimum utilisation of the Fec B gene in prime lamb production systems will require additional management inputs to capitalise on the increased LS of ewes carrying one copy of the Fec B gene.

The lack of difference between the C and the ++ ewes in all of the ewe reproduction and productivity traits is perhaps surprising given that the CSIRO Booroola Merino flock was under continuous selection for increased reproduction rate from 1965 to 1990. However, this outcome may have been a consequence of the selection process focussing on recruiting Fec B genotypes (bb and b+) resulting in the development of a negative linkage disequilibrium between the Fec B locus and reproduction trait genes of small effect. In these situations, the polygenic values are negatively selected (e.g. Gibson 1994).

Utilisation of the Fec B gene in prime lamb production systems has been facilitated by the transfer of the Fec B gene into the Border Leicester breed creating a new sheep breed named the Booroola Leicester (Bindon *et al*. 1997). Rams homozygous for Fec B can be utilised to create BLxMerino ewes heterozygous for Fec B with prolificacy (LB/EL) 20-40 % higher than traditional BLxM ewes. And, as outlined above, the increased prolificacy, may be converted into increased $ ret/EJ by appropriate additional management inputs.

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