CONSEQUENCES OF EXTENSIONS TO THE ADDITIVE-DOMINANCE MODEL ON PREWEANING WEIGHT GAIN OF *Bos taurus* x *Bos indicus* CALVES. A REVIEW


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INTRODUCTION

The objective of this review paper is to discuss estimates of genotypic effects on preweaning average daily weight gain (ADG) of advanced generations of Braford populations (ranging from pure Hereford to pure Brahman-Nelore) obtained by Arthur et al. (1999) and Fries et al. (2000) from experimental data in Australia and Piccoli et al. (2002) from a large commercial crossbred population in Brazil.

RESULTS FROM BRAFORD – CONEXÃO DELTA G

Piccoli et al. (2002) reported estimates of genotypic and genotypic*latitude effects on ADG of 109,614 Hereford x Nelore calves based on data from Conexão Delta G, a commercial beef breeding program, with participating herds from latitude 14°S to 31°S.

Figure 1 depicts changes in ADG based on estimates of individual and maternal additive, complementarity, heterotic and epistatic effects, and interactions of these effects with latitude from consecutive generations, when forming a Braford synthetic ½ at latitude 30.

![Preweaning ADG according to generations of Braford ½, starting out of Hereford (HER) or Nelore (NEL) cows at latitude 30°S](image_url)

Figure 1. Preweaning ADG according to generations of Braford ½, starting out of Hereford (HER) or Nelore (NEL) cows at latitude 30°S
The general form of these predictions agrees with results from Australia, reported by Fries et al. (2000) and discussed later. Generation 0 showed a small difference in ADG between pure Hereford (HER) and pure Nelore (NEL). In comparison with original populations, Generation 1 shows a large difference in maternal additive effect favoring F1 calves out of NEL dams (13.7% higher ADG) in comparison with F1 calves out of HER dams (5.7%). This maternal effect can explain at least part of the initial success obtained in Central Brazil by almost all crossbreeding initiatives. F2 calves do even better (16%) due to full maternal heterosis, even though individual heterosis is reduced to one half and individual epistasis is the largest. F2 dams express full maternal epistasis (-8.6%) and half maternal heterosis, what results in ADG from F3 calves being only 9.1% above NEL. In the F4, advantages stabilize at 14.2% or 13.4% with respect to HER or NEL, respectively.

Arthur et al. (1999) found evidence of heterotic and epistatic effects on 15 genotypes from Brahman x Hereford crossbred cattle and of interactions of additive and heterotic effects with environment at Ebor and Grafton in the State of New South Wales, Australia. Fries et al. (2000) reported location interactions with the same two genotypic components. Piccoli et al. (2002) found even larger interactions, what was expected given the range of latitudes of their analyses. But the latter only found interactions between additive and additive*additive (complementarity) with latitude. Interactions between heterotic and epistatic effects were also tested, but were abandoned due to the size of collinearities. Figure 2 is an extension from Figure 1 and it was obtained using estimates from Piccoli et al. (2002).

![Figure 2. Preweaning ADG from initial generations during the formation of a synthetic Braford ½ at temperate to tropical latitudes out of Nelore cows](image)

Generation 0 shows differences in genetic adaptation of the Nelore genotype at different latitudes as if no other environmental differences existed. Generation 1 shows that there is a
positive and strong interaction between the genotype of the Nelore dam and her F1 calf at every latitude studied. One can speculate that this initial benefit is responsible for the widespread use of crossbreeding, even though the benefit varied from 7 to 13% according to latitude. F2 should show maximum benefits, arising mainly from full maternal heterosis, and this is the case in temperate latitudes, where F1 dams are well adapted. But, at latitudes 25, 20, and 15, interactions between direct and maternal complementarities (additive*additive) with latitude caused the F2 to grow less than the F1. At latitude 15, the F2 calves did worse (-3.1%) than the purebred Nelore. Direct and maternal additive, and complementarity covariates stabilize at F2 generation. Figure 2 shows that the curves for each latitude maintain proportional differences after this point. F3 generations shows the lowest performance in every latitude given maximum combination of negative direct and maternal (dam is F2) epistatic effects. At latitude 20, production level stabilizes (generation F4 onwards) at exactly 99.53% from what it was at generation 0 (purebred Nelore).

RESULTS FROM BRAFORD – GRAFTON, NSW AT 29.7°S
Fries et al. (2000) reported estimates of individual and maternal additive, joint-additive, heterotic and epistatic effects on weaning weights (WW) and these were used to obtain predictions of different crossbreeding systems. Figure 3 presents several scenarios, considering synthetic (1/2, 5/8, and ¼) or rotational (2 breeds) crossbreeding schemes, all at Grafton. Brahmans are used as the initial population and all results presented are with respect to HER. When considering the formation of a synthetic ½, the F1 benefits, mainly from individual heterosis, result in 15.5% of advantage over HER. In next generation, F2 calves do even better (19.2%) due to full maternal heterosis (14.4%), even though individual heterosis is reduced to one half and individual epistasis is the largest (-5.3%). F2 dams express full maternal epistasis (-7.0%) and half maternal heterosis, what result in WW from F3 being only 6 kg above pure Brahmans.

Figure 3. Weaning weight superiority of different synthetics during their formation in the sub-tropics (NSW, Australia) out of Brahman cows (from Fries et al., 2000)
Higher segregation than in purebreds is also expected and a few F3 may be lighter than the worst Brahmans and this may be considered as a failure of the breeding program. In the next generation, WW should stabilize at 12.2 kg (6.8%) above the production level of pure Brahmans. Their conclusion was that, if epistatic effects are considered when modeling data from crossbred cattle, then gains in accuracy can be expected when: (1) designing and predicting results of advanced generations of crossbred populations; and (2) running across- or multi-breed genetic evaluations.

FINAL REMARKS
The combined results discussed in this paper seem to indicate that part of what has been estimated as heterosis can be interpreted as complementarity. Complementarity is the interaction of additive (say for growth or high metabolism from *Bos taurus*) by additive (say for adaptation to heat and/or parasite stresses from *Bos indicus*). If that is not the case, then one can think that this term can help to model non-linear additive effects observed, when the genetic composition increases by 0.25 over a base 0.00 or over a base 0.50 *Bos indicus*. In the report from Piccoli et al. (2002), the genetic components with largest determination on performance were the interaction terms between additive and complementarity effects with latitude. Therefore, caution should be taken when planning crossbreeding programs as these interactions negate paradigms such as “best genotypes for all” and “maximum retained heterosis”.

If heterosis is the benefit that accrues from recovery of inbreeding depression in pure populations, epistasis is the negative balance brought up by these benefits and which will follow up in next generation. Plans to develop synthetic/composites should consider:
1. Use one purebred parent at critical generations to reduce individual epistasis;
2. Minimize participation of F2 dams, which exhibit maximum maternal epistasis.

Consideration of epistatic effects allows for alternative tactics, when using the next strategies:

**A** **Composites.** Cross different F1’s, to maximize heterotic benefits and to postpone epistatic losses, which follow heterosis by one generation.

**B** **Terminal crosses.** Exploit maximum heterosis and send to market products from F1_{AB} (paternal line) X F1_{CD} (maternal line). These have maximum recombination or epistatic losses but dams, being F1’s, have none. This scheme is a way to avoid the use of F2 or back-cross dams which may explain why it is so popular in other industries.

**C** **Selection within composites and synthetics.** Crisscrossing for the first generations allows to benefit from the best additive resources from each breed, maintain high heterozygosities, and reduce epistatic losses. If a model accounting for all components is used, then selection will be more accurate and effective in recreating positive epistatic interactions.

REFERENCES

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