Genotype × Environment Interactions in Preweaning Traits of Purebred and Reciprocal Cross Angus and Brahman Calves on Common Bermudagrass and Endophyte-Infected Tall Fescue Pastures


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ABSTRACT: Preweaning data on 486 Angus, Brahman, and reciprocal cross calves (AB, BA) managed on common bermudagrass or endophyte-infected tall fescue were used to evaluate the interactions of forage type and sex of calf with direct effects, individual heterosis, and maternal effects. Calves were spring-born in 1988, 1989, 1990, and 1991 to five sires of each breed. Male calves were castrated at birth, and calves were not creep-fed. Average values of heterosis for birth weight, 205-d weight, weaning hip height, and weaning weight:height ratio (WT/HT) were important (P < .01) and consistent across forage environment. Heterosis for birth weight was larger in bull calves than in heifer calves (P < .05), whereas heterosis for other preweaning traits were consistent across sex of calf. Average maternal effects for WT/HT (P < .10) were important and consistent across forage environment. Maternal effects for birth weight were larger with bull calves than with heifer calves (P < .01). Maternal effects for weaning weight and height were larger in bull calves than in heifer calves (P < .05). Direct effects for birth weight were larger in calves managed on bermudagrass than in calves managed on tall fescue (P < .07). A similar but nonsignificant trend was evident in maternal effects for 205-d weight. Direct effects for heifer weight were larger in bull calves than in heifer calves (P < .01). Direct effects for weaning height were larger in calves managed on bermudagrass than in calves managed on tall fescue (P < .07). A similar but nonsignificant trend was evident in direct effects for 205-d weight. Direct effects for WT/HT were relatively small and unimportant. These data indicate that heterosis for preweaning traits reported in this research are relatively stable across the two forage environments but maternal and direct effects may vary with production environment.

Key Words: Genotypes, Environment, Forage, Beef Cattle, Heterosis, Maternal Effects

Introduction

The design of efficient beef cattle/forage systems requires that components of such systems be properly matched. The concept of matching animal genetic resources with production environment, considered by Wright (1939) and Lush (1951), has been of recent interest. Heterosis, maternal effects, and direct genetic effects are genetic resources that have been used in improving the efficiency of commercial cattle production. There is evidence that these genetic effects may not be stable across production environments (Koger et al., 1975, 1979; Burns et al., 1979; Long, 1980; Barlow, 1981; Bolton et al., 1987a,b). However, there have been few studies specifically designed to investigate the interaction of heterosis with environment (Barlow, 1981) and little evidence exists in the literature on interactions of maternal or direct genetic effects with specific production environments.

It is important, therefore, that work be done to evaluate the potential for interactions of genetic effects with production environments in beef cattle so that specific recommendations can be developed for...
beef/forage systems. The objectives of this research were to evaluate heterosis, maternal, and direct genetic effects for preweaning performance in straightbred and reciprocal cross calves from Angus and Brahman dams managed under two different nutritional environments, endophyte-infected tall fescue or common bermudagrass.

Materials and Methods

Eighty purebred Angus and 80 purebred Brahman heifers born in the spring of 1985 were purchased from approximately 20 different sources per breed in the fall of 1985 and winter of 1986. In the purchased heifers, 32 and 30 different sires were represented in Angus and Brahman, respectively. Heifers were stratified according to source and assigned at random to one of four 16-ha common bermudagrass pastures (Cynodon dactylon [L.] Pers.) and one of four 16-ha ‘Kentucky-31’ endophyte-infected tall fescue pastures (Festuca arundinacea Schreb.).

The soil type of these pastures was a Leadvale silt loam (fine-silty, siliceous, thermic, Typic Fragiudults). Fertilizer N was applied to tall fescue pastures in February and September and to bermudagrass pastures in April and July to furnish 60.1 kg of N/ha for each date. Fertilizer P and K were maintained at moderate levels, and nutrient applications were made in the fall of each year to meet soil test recommendations. Pastures were shredded in early summer to remove seed heads in tall fescue and in late summer to control broadleaf weeds in bermudagrass.

Stocking rate for each pasture within forage environment ranged from 19 to 24 heifers, with approximately equal numbers of Brahman and Angus. Heifers were managed as commercial replacement heifers to gain approximately .35 kg/d by supplementing with cottonseed meal, corn, and tall fescue or bermudagrass hay according to visual estimates of forage DM availability and normal quality curves for either common bermudagrass or endophyte-infected tall fescue. Normally, supplemental feed was provided from late November to late April in both forages; supplemental grain (.9 kg per animal per day) was continued in the tall fescue environment in the late fall and early spring in an attempt to moderate potential toxicity from the forage. Minerals were fed free choice throughout the year.

Heifers were managed to calve as 3-yr-olds to preclude parity differences between the breeds and were bred during 75-d breeding seasons starting in early June in 1987 and late May in 1988, 1989, and 1990. Four Brahman and four Angus sires were used each year. Three Brahman and three Angus sires were used each year of the study. A Brahman sire used in 1987 and 1988 died and was replaced with another Brahman for the 1989 and 1990 breeding seasons. An Angus sire used in 1987, 1988, and 1989 died and was replaced with another Angus for the 1990 breeding season. Thus, five sires of each breed were ultimately used in the study. Sires were rotated among breeding pastures in both forage treatments to prevent confounding of sire and forage effects, and breed of sire was alternated in a breeding pasture to facilitate sire of calf identification. In 1987, sires were rotated based on evidence of breeding activity using heat detection patches and in subsequent years, rotation was done 9, 10, and 18 d into the breeding season with only three rotations necessary to cross sire with dam breed and forage.

Calves were born from late February to late May each year. Weights were taken, and calves were tagged at birth; bull calves were castrated by banding. Calves were weighed every 28 d while nursing cows with no shrinkage before weights. Weights and hip heights were taken at weaning in late October of each year after a 14-h shrinkage. Age at weaning averaged 204 d; weights at weaning were adjusted to an average 205 d of age before analyses. Calves were not creep-fed in any year.

The ratio of weaning weight:weaning height (WT/HT) was calculated to estimate weaning condition. This ratio has been used as a predictor of body composition in mature cows (Klosterman et al., 1968; Lemenager and Martin, 1982; Nelsen et al., 1985), is less subjective than visual estimates of condition score (Lemenager and Martin, 1982), and is useful in describing the condition of cows that may vary widely in type and size (Klosterman et al., 1968).

Data were analyzed by methods of least squares using the GLM procedure of SAS (1990). Initial linear models included effects of sire breed, sire nested in sire breed, dam breed, forage, sex of calf, year of birth, and all possible two-, three-, and four-factor interactions. Sire nested in breed of sire and associated interactions with this effect were considered random effects. Sire breed, dam breed, forage, sex of calf, and associated interactions were considered fixed effects. Year effects were treated as random duplicate samples. Secondary analyses were performed to test sex × dam breed × sire in sire breed, forage × sex × sire in sire breed, and forage × dam breed × sire in sire breed using forage × sex × dam breed × sire in sire breed. There was little evidence (P > .15) that the expectation of these mean squares differed from the appropriate error and they were pooled. Tertiary analyses were performed similarly to test sex × sire in sire breed, forage × sire in sire breed, and dam breed × sire in sire breed with the pooled forage × sex × dam breed × sire in sire breed from the previous analyses with similar results. Data were averaged across year within sire breed, sire nested in sire breed, dam breed, forage, and sex of calf subclasses to facilitate the mixed-model analyses. Consequently, the final model included
Table 1. Samples sizes for forage treatment, sex, sire breed, and dam breed classes and subclasses for birth weight and other preweaning traits

<table>
<thead>
<tr>
<th>Class</th>
<th>A × A</th>
<th>A × B</th>
<th>B × A</th>
<th>B × B</th>
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<tr>
<td>n</td>
<td>163</td>
<td>110</td>
<td>89</td>
<td>124</td>
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<tr>
<td>Bermuda</td>
<td>90</td>
<td>64</td>
<td>50</td>
<td>71</td>
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<tr>
<td>Fescue</td>
<td>73</td>
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<td>53</td>
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<td>30</td>
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<tr>
<td>Steers</td>
<td>43</td>
<td>24</td>
<td>18</td>
<td>26</td>
</tr>
</tbody>
</table>

a205-d weight, weaning hip height, and weaning weight-height ratio. A = Angus, B = Brahman, sire breed listed first.

Table 2. Analysis of variance tables for preweaning traits

<table>
<thead>
<tr>
<th>Source</th>
<th>Birth wt, kg</th>
<th>205-d wt, kg</th>
<th>Weaning hip ht, cm</th>
<th>Weaning wt/ht, kg/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>df</td>
<td>MS</td>
<td>F</td>
<td>OSL</td>
</tr>
<tr>
<td>Sire brd</td>
<td>1</td>
<td>2,277.59</td>
<td>20.06</td>
<td>.0021</td>
</tr>
<tr>
<td>Sire(sire brd)</td>
<td>8</td>
<td>113.51</td>
<td>4.17</td>
<td>.0006</td>
</tr>
<tr>
<td>Dam brd</td>
<td>1</td>
<td>4,996.82</td>
<td>183.72</td>
<td>.0001</td>
</tr>
<tr>
<td>Sire brd × dam brd</td>
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<td>1,495.85</td>
<td>54.99</td>
<td>.0001</td>
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<td>Forage</td>
<td>1</td>
<td>50.78</td>
<td>1.87</td>
<td>.1776</td>
</tr>
<tr>
<td>Forage × dam brd</td>
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<td>52.00</td>
<td>1.91</td>
<td>.1726</td>
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<tr>
<td>Sex</td>
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<td>1,195.00</td>
<td>44.08</td>
<td>.0001</td>
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<td>336.59</td>
<td>12.37</td>
<td>.0009</td>
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<td>Forage × dam brd</td>
<td>1</td>
<td>40.05</td>
<td>1.77</td>
<td>.1895</td>
</tr>
<tr>
<td>Forage × sire brd × dam brd</td>
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<td>.03</td>
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<tr>
<td>Forage × sex</td>
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<td>37.57</td>
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<td>.2452</td>
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<tr>
<td>Forage × sex × sire brd</td>
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<td>.18</td>
<td>.01</td>
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<tr>
<td>Sex × dam brd</td>
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<td>225.18</td>
<td>8.28</td>
<td>.0058</td>
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<td>Sex × sire brd × dam brd</td>
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<td>110.72</td>
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<td>.0487</td>
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<tr>
<td>Forage × sex × dam brd</td>
<td>1</td>
<td>51.85</td>
<td>1.91</td>
<td>.1732</td>
</tr>
<tr>
<td>Forage × sex × sire brd × dam brd</td>
<td>1</td>
<td>2.98</td>
<td>.11</td>
<td>.7420</td>
</tr>
<tr>
<td>Error</td>
<td>—</td>
<td>27.20</td>
<td>—</td>
<td>—</td>
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</table>

aOsl = observed significance level.
bError df were 53 for birth weight and 52 for 205-d weight, weaning hip height, weaning weight/height ratio.
evaluated in this study but were chosen to represent a random sample of contemporary blood lines in each breed. Comparisons among genetic effects were made using single degree of freedom linear contrasts. Sample sizes summed over years are given in Table 1.

### Results and Discussion

Analysis of variance tables for preweaning traits are given in Table 2. Generally, sire effects, dam breed, sire breed × dam breed, and sex effects were important for all traits studied. Sire breed effects were important for birth weight and weaning hip height. Forage effects were significant for preweaning ADG, 205-d weight, and weaning WT/HT, and forage effects interacted with both sire breed and dam breed (P < .10) for weaning hip height. Sire breed × dam breed effects for birth weight were not the same in both sexes (P < .05). Dam breed effects were different in heifer calves compared with steer calves in birth weight (P < .01) and weaning hip height (P < .10) and sire breed effects for birth weight were not the same in both sexes (P < .01).

**Birth Weight.** Averaged over sire and dam breed, there was little evidence of forage differences in birth weight in either sex in spite of the higher nutritional level of tall fescue during portions of the last trimester of pregnancy (Table 3). Averaged over forage, steers exceeded heifers in birth weight by 3.3 kg (P < .01).

There was also little evidence of a forage × sex interaction for heterosis, maternal effects, or direct effects for birth weight and these effects were consistent across forages when averaged over sex of calf. There was evidence that heterosis, maternal effects, and direct effects were not consistent across sex of calf (P < .05).

Heterosis for birth weight was larger in steers (4.7 kg, P < .01) than in heifers (2.7 kg, P < .01). These results are similar to work reported by Ellis et al. (1965) in Brahman and Hereford crosses of both sexes but contrast with work reported by Turner and McDonald (1969), who found heterosis in Brahman and Angus crosses to be numerically less in steers. Heterosis averaged over sex in this study was comparable with other estimates in the literature (Cartwright et al., 1964; Reynolds et al., 1980; Roberson et al., 1986; Comerford et al., 1987).

Maternal contrasts for birth weight were larger in steers (-13.7, P < .01) than in heifers (-7.4, P < .01), where negative values indicate lower birth weights in the Brahman dams. This interaction agrees with work by Ellis et al. (1965) in both sign and magnitude. It is also consistent with results of Ferrell (1991), who concluded that the lower birth weights in Brahman cows are a result of lower umbilical blood flow. It would seem reasonable that greater umbilical blood flow in Angus would allow expression of both sex differences and heterozygosity in birth weight, whereas this might be inhibited in Brahman. Average maternal contrasts in this study were similar to estimates reported by Roberson et al. (1986) and Comerford et al. (1987) but were larger in magnitude than those reported by Reynolds et al. (1980).

Direct breed contrasts for birth weight were also larger for steers (-11.2, P < .01) than for heifers (-4.2, P < .01), where negative values indicate higher birth weights from the Brahman sires. This also agrees with work by Ellis et al. (1965) and Turner and McDonald (1969), who reported larger direct effects in steers than heifers. When averaged over sex of calf, estimates from the current study were slightly larger but of the same sign as estimates in the literature (Reynolds et al., 1980; Roberson et al., 1986; Comerford et al., 1987).

### Table 3. Least squares means, heterosis, maternal, and direct breed effects and associated standard errors for birth weight [kg]

<table>
<thead>
<tr>
<th>GENOTYPE × ENVIRONMENT IN PREWEANING TRAITS</th>
<th>329</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Class</th>
<th>A × A</th>
<th>A × B</th>
<th>B × A</th>
<th>B × B</th>
<th>Heterosis</th>
<th>Maternal</th>
<th>Direct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bermuda</td>
<td>34.6 ± .5</td>
<td>31.5 ± .6</td>
<td>42.1 ± .6</td>
<td>31.7 ± .5</td>
<td>3.7 ± .5**</td>
<td>-10.6 ± .8**</td>
<td>-7.6 ± 1.2**</td>
</tr>
<tr>
<td>Fescue</td>
<td>35.0 ± .6</td>
<td>31.2 ± .7</td>
<td>41.7 ± .8</td>
<td>30.7 ± .7</td>
<td>3.6 ± .7</td>
<td>-10.5 ± 1.1</td>
<td>-6.2 ± 1.4</td>
</tr>
<tr>
<td>Fescue</td>
<td>34.2 ± .7</td>
<td>31.9 ± .8</td>
<td>42.5 ± .9</td>
<td>32.6 ± .7</td>
<td>3.8 ± .8</td>
<td>-10.6 ± 1.2</td>
<td>-9.0 ± 1.6</td>
</tr>
<tr>
<td>Heifers</td>
<td>33.6 ± .6</td>
<td>31.0 ± .7</td>
<td>38.4 ± .8</td>
<td>30.4 ± .7</td>
<td>2.7 ± .7x</td>
<td>-7.4 ± 1.1x</td>
<td>-4.2 ± 1.4x</td>
</tr>
<tr>
<td>Steers</td>
<td>35.6 ± .7</td>
<td>32.1 ± .8</td>
<td>45.8 ± .8</td>
<td>33.0 ± .7</td>
<td>4.7 ± .7x</td>
<td>-13.7 ± 1.1y</td>
<td>-11.2 ± 1.6y</td>
</tr>
<tr>
<td>Steers</td>
<td>33.8 ± .8</td>
<td>31.3 ± .9</td>
<td>38.0 ± 1.1</td>
<td>30.0 ± 1.0</td>
<td>2.8 ± .9</td>
<td>-6.7 ± 1.4x</td>
<td>-2.8 ± 2.0x</td>
</tr>
<tr>
<td>Bermuda</td>
<td>33.4 ± .8</td>
<td>30.7 ± 1.1</td>
<td>38.7 ± 1.2</td>
<td>30.8 ± 1.0</td>
<td>2.6 ± 1.1</td>
<td>-8.1 ± 1.6x</td>
<td>-5.4 ± 2.2x</td>
</tr>
<tr>
<td>Bermuda</td>
<td>36.1 ± .8</td>
<td>31.0 ± 1.0</td>
<td>45.4 ± 1.1</td>
<td>31.4 ± .8</td>
<td>4.4 ± 9.3</td>
<td>-14.3 ± 1.5x</td>
<td>-9.6 ± 2.0x</td>
</tr>
<tr>
<td>Bermuda</td>
<td>35.0 ± 1.0</td>
<td>33.2 ± 1.2</td>
<td>46.3 ± 1.2</td>
<td>34.5 ± 1.0</td>
<td>4.9 ± 1.1</td>
<td>-13.1 ± 1.6x</td>
<td>-12.6 ± 2.2x</td>
</tr>
</tbody>
</table>

**a** = Angus, **B** = Brahman, sire breed listed first.

**b** = (A × A + A × B) - (B × A + B × B).

**c** = Class/subclass means within a column lacking a common superscript letter differ (P < .05).

**x** = P < .01.
The larger heterosis in male calves, larger direct
effect in male calves, and apparent inability of the
Angus dam to suppress the birth weight of the male
calves suggests that technology to alter sex ratios may
be beneficial when producing Brahman-sired calves
from cows of British breeds to produce a higher
proportion of heifer calves. This would have a dual
economic benefit; heifer calves from this cross have a
higher economic value than steers and the lighter
heifer birth weights result in lower levels of calving
difficulty and associated subsequent reproductive
problems in the dams. The lack of forage effects on
birth weight in this study suggests a reasonable
stability of heterosis, maternal effects, and direct
breed effects across these two forage environments.

205-Day Weight. Averaged over sire breed and dam
breed, forage effects for 205-d weight were similar for
each sex (Table 4). Steers exceeded heifers by 11.4 kg
(P < .01). Forage differences averaged over sire and
dam breed and sex of calf were 17.6 kg (P < .01) in
favor of common bermudagrass. Endophyte-infected
tall fescue has been implicated in poorer preweaning
performance in other studies (Burns et al., 1973;
Smith et al., 1975; Hill et al., 1979; Holloway et al.,
1979; Ellis et al., 1983; Ashley et al., 1987; Gay et al.,
1987; Tucker et al., 1989).

Estimates of heterosis for 205-d weight were
consistent across forage environment and sex of calf
and averaged 28.0 kg (P < .01). Direct effects were
smaller and averaged -12.2 kg (P < .14) on ber-
mudagrass and -2.8 kg (P > .75) on tall fescue.
Maternal effects averaged -11.5 kg (P < .06) on ber-
mudagrass and -5.2 kg (P > .42) on tall fescue.
Estimates of heterosis from this research were com-
parable to higher estimates in the literature (Cart-
wright et al., 1964; Koger et al., 1975; Peacock et al.,
1978; Roberson et al., 1986), but were somewhat
higher than values reported by Damon et al. (1961)
and Turner and McDonald (1969). The estimates of
maternal contrasts in this study were closest to those
reported by Peacock et al. (1978), but other estimates
from the literature favored the Brahman dam and
were larger (Koger et al., 1975; Roberson et al.,
1986). Estimates of direct effects from this study were
smaller than those reported by Turner and McDonald
(1969) but of the same sign and were similar to those
reported by Koger et al. (1975) on native Florida
pasture and by Peacock et al. (1978). Roberson et al.
(1986) reported a small direct effect in favor of the
Hereford sire.

The maternal effects estimated in this study may
differ from estimates in the literature because of
potential interactions of these effects with location of
study (i.e., Texas and Florida where Brahman may be
better adapted compared with west-central Arkan-
sas). Burns et al. (1979) and Pahnish et al. (1985)
reported significant line x location interactions for
weaning weight in beef cattle. There was a nonsignif-
cant trend for maternal effects estimated in this study
to be larger on bermudagrass and this was consistent
with dam breed differences in milk production ob-
served in these cattle on the two forages (Brown and
Tharel, 1991). Koger et al. (1975) reported maternal
contrasts for 205-d weight for Brahman and Shorthorn
largest on Florida native pastures, intermediate on
combinations of native and improved pastures, and
lowest on improved pastures, where all contrasts were
in favor of the Brahman dam. The environment in
Arkansas seems to be more favorable to dams of
British breeds but the advantage in Angus dams
compared with Brahman in this study was less in the
poorer nutritional environment (tall fescue). Thus,
these data agree with the findings of Koger et al.
(1975) in showing a compensation by the Brahman
dam in a poorer nutritional environment. It does not
seem, however, that the forage environments evalu-
ated in this study resulted in a differential response in
heterosis.
Weaning Hip Height. Averaged over sire and dam breed, sex of calf differences in weaning hip height were consistent across forages and averaged 110.7 cm for heifers and 113.2 cm for steers (P < .01) (Table 5). Forage differences were small and unimportant. There was little indication of forage x sex interactions with heterosis, maternal effects, or direct effects for weaning hip height nor was there evidence of interactions of these effects with sex of calf. Heterosis, averaged over forage and sex of calf averaged 4.2 cm (P < .01). There was evidence of interactions of maternal effects (P < .05) and direct effects (P < .07) with forage environment. Maternal contrasts on bermudagrass were -2.7 cm (P < .05) and on tall fescue were 1.7 cm (P > .22). Direct effects on bermudagrass averaged -9.4 cm (P < .01) and -4.8 cm (P < .05) on tall fescue.

In weaning hip height, calves from Angus dams seemed to receive a maternal advantage on bermudagrass, but not on tall fescue. Conversely, calves from Brahman sires received a direct breed advantage on both forages but it was larger on bermudagrass. These two effects tended to offset each other, making purebred differences very similar between the two forages.

Weaning Weight:Height Ratio. Averaged over sire and dam breed, calves on bermudagrass had higher (P < .01) WT/HT than did calves on tall fescue (1.86 vs 1.71 kg/cm, respectively) and steers were significantly higher than heifers (1.81 vs 1.76, P < .01) (Table 6).

Table 5. Least squares means, heterosis, maternal, and direct breed effects and associated standard errors for weaning height (cm)

<table>
<thead>
<tr>
<th>Class</th>
<th>A x A</th>
<th>A x B</th>
<th>B x A</th>
<th>B x B</th>
<th>Heterosis</th>
<th>Maternal</th>
<th>Direct</th>
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<tbody>
<tr>
<td>Bermuda</td>
<td>106.5 ± .6</td>
<td>113.8 ± .7</td>
<td>114.3 ± .7</td>
<td>113.2 ± .6</td>
<td>4.2 ± .6**</td>
<td>-.5 ± 1.0</td>
<td>-7.2 ± 2.6**</td>
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<td>Fescue</td>
<td>106.7 ± .7</td>
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<td>3.7 ± .8</td>
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<tr>
<td>Heifers</td>
<td>106.4 ± .9</td>
<td>115.2 ± .9</td>
<td>113.5 ± 1.1</td>
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<td>4.7 ± .9</td>
<td>1.7 ± 1.4y</td>
<td>-4.8 ± 2.0w</td>
</tr>
<tr>
<td>Steers</td>
<td>105.9 ± .7</td>
<td>111.7 ± .9</td>
<td>113.5 ± 1.0</td>
<td>111.7 ± .9</td>
<td>3.8 ± .8</td>
<td>-1.8 ± 1.3</td>
<td>-7.6 ± 1.8</td>
</tr>
<tr>
<td>Bermuda</td>
<td>107.2 ± .8</td>
<td>115.9 ± 1.0</td>
<td>115.1 ± 1.0</td>
<td>114.8 ± .8</td>
<td>4.5 ± .9</td>
<td>.9 ± 1.4</td>
<td>-7.8 ± 2.0</td>
</tr>
<tr>
<td>Fescue</td>
<td>107.3 ± 1.3</td>
<td>117.7 ± 1.4</td>
<td>113.6 ± 1.5</td>
<td>114.7 ± 1.2</td>
<td>4.6 ± 1.3</td>
<td>4.1 ± 2.0y</td>
<td>-3.4 ± 2.8w</td>
</tr>
</tbody>
</table>

A = Angus, B = Brahman, sire breed listed first. 
\( A \times B - B \times A \) 
\( (A \times A + A \times B) - (B \times A + B \times B) \) 
\( P < .10 \) 
**P < .01.

Table 6. Least squares means, heterosis, maternal, and direct breed effects and associated standard errors for weaning weight/height (kg/cm)

<table>
<thead>
<tr>
<th>Class</th>
<th>A x A</th>
<th>A x B</th>
<th>B x A</th>
<th>B x B</th>
<th>Heterosis</th>
<th>Maternal</th>
<th>Direct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bermuda</td>
<td>1.75 ± .02</td>
<td>1.85 ± .02</td>
<td>1.91 ± .02</td>
<td>1.64 ± .02</td>
<td>.18 ± .02**</td>
<td>-.06 ± .03†</td>
<td>.06 ± .06</td>
</tr>
<tr>
<td>Fescue</td>
<td>1.81 ± .03</td>
<td>1.94 ± .03</td>
<td>1.99 ± .03</td>
<td>1.71 ± .03</td>
<td>.20 ± .03</td>
<td>-.05 ± .05</td>
<td>.06 ± .06</td>
</tr>
<tr>
<td>Heifers</td>
<td>1.68 ± .03</td>
<td>1.75 ± .03</td>
<td>1.82 ± .04</td>
<td>1.57 ± .05</td>
<td>.16 ± .03</td>
<td>-.07 ± .06</td>
<td>.04 ± .06</td>
</tr>
<tr>
<td>Steers</td>
<td>1.73 ± .03</td>
<td>1.81 ± .03</td>
<td>1.87 ± .03</td>
<td>1.61 ± .03</td>
<td>.17 ± .03</td>
<td>-.06 ± .06</td>
<td>.06 ± .06</td>
</tr>
<tr>
<td>Bermuda</td>
<td>1.76 ± .03</td>
<td>1.85 ± .03</td>
<td>1.94 ± .04</td>
<td>1.67 ± .03</td>
<td>.20 ± .03</td>
<td>-.06 ± .06</td>
<td>.04 ± .06</td>
</tr>
<tr>
<td>Fescue</td>
<td>1.81 ± .03</td>
<td>1.89 ± .04</td>
<td>1.95 ± .04</td>
<td>1.69 ± .04</td>
<td>.17 ± .04</td>
<td>-.06 ± .06</td>
<td>.06 ± .08</td>
</tr>
<tr>
<td>Steers</td>
<td>1.66 ± .04</td>
<td>1.75 ± .05</td>
<td>1.78 ± .05</td>
<td>1.52 ± .05</td>
<td>.16 ± .05</td>
<td>-.05 ± .07</td>
<td>.08 ± .10</td>
</tr>
<tr>
<td>Bermuda</td>
<td>1.82 ± .04</td>
<td>1.99 ± .04</td>
<td>2.02 ± .05</td>
<td>1.72 ± .04</td>
<td>24 ± .04</td>
<td>-.03 ± .06</td>
<td>.06 ± .08</td>
</tr>
<tr>
<td>Fescue</td>
<td>1.71 ± .04</td>
<td>1.77 ± .05</td>
<td>1.87 ± .05</td>
<td>1.61 ± .04</td>
<td>16 ± .05</td>
<td>-.09 ± .07</td>
<td>.00 ± .10</td>
</tr>
</tbody>
</table>

A = Angus, B = Brahman, sire breed listed first. 
\( A \times B - B \times A \) 
\( (A \times A + A \times B) - (B \times A + B \times B) \) 
\( P < .10 \) 
**P < .01.
Discussion

Given the substantial reduction in weaning weights and the differences in weaning WT/HT, it is apparent that endophyte-infected tall fescue and common bermudagrass are two very different nutritional environments. In spite of the difference, there was very little evidence to suggest that heterosis for any of the traits studied interacted with forage environment. Barlow (1981) suggested that heterosis for growth should be larger in better nutritional environments. The results of the current study suggest that differences in nutritional environments must be larger than differences between common bermudagrass and endophyte-infected tall fescue before differences in heterosis will occur. Koger et al. (1975) reported similar levels of heterosis for 205-d weight on Florida native pastures, native and improved pasture combinations, and improved pastures, respectively.

Maternal effects and direct effects in this study showed a tendency to be less stable across forage environment. Maternal effects for weaning hip height interacted with forage environment; Angus dams had the advantage on bermudagrass but not on fescue and direct effects for weaning hip height were larger on bermudagrass than on tall fescue. Although comparisons of the maternal and direct effects for 205-d weight between forages were not statistically significant, they were larger on bermudagrass than on fescue, consistent with the results in weaning hip height. This suggests that maternal effects for growth could vary with nutritional environment. It also suggests that the Brahman dam may be more tolerant of the poorer nutritional environment, consistent with the results of Koger et al. (1975). The ranking of the maternal effects across forage is consistent with the interaction between dam breed and forage in milk production in these cattle (Brown and Tharel, 1991) for which Angus were more affected by endophyte-infected fescue than were Brahman. Notter et al. (1978) reported that rankings for milk production in several breeds corresponded closely to rankings of maternal effects for 200-d weight. Similar to maternal effects for 205-d weight, direct breed effects for 205-d weight were numerically larger on common bermudagrass than on fescue, suggesting the possibility that direct effects for growth may also vary with nutritional environment.

The direction and magnitude of these differences in maternal and direct effects may also depend on the relative adaptation of the breeds to the production environment in which they are contrasted. There is a need to study a wider range of production and nutritional environments to evaluate more comprehensively the relationships of heterosis, maternal effects, and direct effects with environment and to determine whether relationships of genetic effects with nutritional environment can be expressed as functional relationships.

Implications

Heterosis, maternal effects, and direct breed effects are important components of cow-calf production systems. It is important to know whether these genetic effects vary across production environments and the nature of this variation, if it exists. Our research did not find evidence of relationships of the level of heterosis to forage environment but did suggest that maternal effects and direct breed effects for weaning weight and hip height may be larger on common bermudagrass than on endophyte-infected tall fescue. Consequently, choices of breeds in crossbreeding systems may depend on the production environment for optimal combinations.

Literature Cited


Bolton, R. C., R. R. Frahm, J. W. Castree, and S. W. Coleman. 1987b. Genotype x environment interactions involving propor-


