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Genotype × environment interactions in Angus, Brahman, and reciprocal-cross cows and their calves grazing common bermudagrass, endophyte-infected tall fescue pastures, or both forages[1,2]

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ABSTRACT: Reproductive and preweaning data on 190 Angus (A × A), Brahman (B × B), and reciprocal-cross cows (A × B and B × A) and 434 two- and three-breed-cross calves managed on common bermudagrass (BG), endophyte-infected tall fescue (E+), or a combination of both forages (ROT) were used to evaluate the interaction of forage type with individual and maternal heterosis and maternal and grandmaternal breed effects. Cows were born from 1988 to 1991, and calves sired by 13 Polled Hereford bulls were born from 1995 to 1997. Heterosis for calving rate was larger on E+ than on BG or ROT ($P < .05$), whereas maternal effects were larger on BG than on ROT ($P < .10$). Maternal heterosis for birth weight was negative on BG ($P < .11$) but positive on E+ and ROT ($P < .10$). Grandmaternal effects were evident on BG ($P < .10$) and E+ ($P < .01$) but not on ROT. Forage effects were generally substantial for 205-d weight, calf weaning hip height, and calf weaning weight:height ratio; BG was highest, ROT was intermediate, and E+ was lowest. Maternal heterosis for these traits was generally greater on E+ than on BG ($P < .10$). Grandmaternal effects for 205-d weight, hip height, and weight:height ratio were not important on any forage. Heterosis for weaning weight per cow exposed was substantial on all forages ($P < .01$) and was significantly greater on E+ ($P < .01$) than on BG or ROT, but maternal effects were not significant. Thus, we observed more advantage to Brahman-cross cows over purebreds on E+ than on BG. We also observed that moving cows and calves from E+ to BG in the summer will alleviate some, but not all, of the deleterious effects of E+ on calf growth, although it may be more beneficial for reproductive traits in purebred cows.

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

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Introduction

The economic sustainability of cow-calf production systems depends on proper utilization of available forages. In the midsouthern United States, common bermudagrass (**BG**) and endophyte-infected tall fescue (**E+**) are the major available warm-season and cool-season forages. Problems with E+ have been extensively documented. Losses in milk production, weaning weight, and reproduction have been reported (Brown et al., 1993a,b, 1996, 1997). Brown et al. (1997) reported that F_1 cows from Brahman and Angus breeds and their three-breed-cross calves were more tolerant of the E+ than their purebred contemporaries, when cows were managed on BG and E+ all year. Sleper and West (1996) suggested that removal of cows from E+ during the summer months is appropriate management of E+ to help alleviate problems associated with this forage. However, there has been little evidence in the literature to document effects of removal during the summer. Moreover, there is some evidence that heterosis and(or) breed effects are not consistent across production environment (Koger et al., 1975, 1979; Burns et al., 1979; Long, 1980; Barlow, 1981; Bolton et al., 1987a,b; Brown et al., 1993a,b,c,d, 1996, 1997). There is little documentation of interactions of genetic effects with management systems involving year-round management on BG, E+, or a system using both forages during appropriate grazing seasons. It would be useful to determine whether removal of cows from E+ during summer would

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enhance apparent tolerance of F_1 cows and their calves to E+ and determine the effects of forage on expression of individual and maternal heterosis. Consequently, our objective for this research was to evaluate reproductive performance of Angus, Brahman, and reciprocal-cross cows and preweaning performance of their three-breed-cross calves when cows and calves were managed on BG, E+, or a combination of the two forages.

Materials and Methods

Approximately 190 Angus (**A** × **A**), Brahman (**B** × **B**), and reciprocal-cross cows (**A** × **B** and **B** × **A**) born in 1988 to 1991 and 434 two- and three-breed-cross calves were used to evaluate the effect of forage management system on reproductive and preweaning performance. These cows had previously been used to evaluate the interaction of forage environment with maternal heterosis and grandmaternal effects from 1991 to 1994 (Brown et al., 1997). Cows were managed on 16-ha pastures (approximately 1.25 cattle/ha) of either BG or E+, and all breed types were represented in each pasture. After weaning in the fall of 1994, approximately 10 cows from each breed group on each forage were randomly assigned to a new forage management treatment: E+ in fall and spring (approximately November to May) and BG in summer (June to October). Consequently, there were three 16-ha pastures of BG, three 16-ha pastures of E+, and two pairs of 16-ha BG and E+ pastures used in the rotational system (**ROT**). Stocking rates were approximately 1.25 cattle/ha for BG and E+ and an average of approximately 1.25 cattle/ha on ROT (approximately 2.5 cattle/ha on BG in summer and approximately 2.5 cattle/ha on E+ in fall and spring). Pastures were fertilized with a total of 155 kg/ha of N in two applications: early May and mid-July for BG and early March and early October for E+. Other soil amendments (P and K) were applied as suggested by soil tests. Eight Polled Hereford bulls were used each year during 1994 to 1996 breeding periods. Thirteen bulls were used throughout the study. Bulls were subjected to breeding soundness exams each year prior to the breeding season. All bulls were used in all forage environments to preclude confounding sire effects with forage effects. Heifers were evaluated for pregnancy by rectal palpation in the fall each year.

Calves were born from late February through May in 1995, 1996, and 1997. Calves were weighed at birth and tagged. Bull calves were castrated at birth by banding. Calves were not creep-fed, and they were weaned at an average age of 205 d. Body weights and hip heights were taken at this time. A description of production and management of purebred and crossbred cows used in this study is given by Brown et al. (1993a).

In the analyses of data, calving percentage and weaning weight per cow exposed for breeding were considered traits of the cow. Weaning traits of 205-d weight, calf hip height, and calf weight:hip height ratio were considered traits of the calf. Data were analyzed using methods of mixed model least squares. The linear model for traits of the cow included effects for sire breed of cow, sire of cow in sire breed, dam breed of cow, forage, age of dam, and appropriate two- and three-factor interactions among the fixed effects; sire in sire breed was considered random and other main effects fixed. The linear model for calf weaning traits included effects of sire of calf, sire breed of cow, dam breed of cow, forage, age of dam, sex of calf, and appropriate interactions among fixed effects; sire of calf was random and other main effects fixed. Individual and maternal heterosis, maternal and grandmaternal breed effects, and interactions of these effects with forage effects were computed from linear contrasts of the least squares means and tested using *t*-statistics. Individual heterosis was obtained as the difference between the means of traits reported for crossbred and purebred cows. Individual heterosis can be interpreted as the advantage in performance of crossbreds over purebreds. Maternal heterosis was obtained as the difference between means of traits reported for calves from crossbred dams and the means of traits reported for calves from purebred dams. Maternal heterosis is the advantage in performance that crossbred calves from crossbred dams have over crossbred calves from purebred dams. Maternal breed effects were obtained as the difference in trait means between reciprocal-cross cows. Generally, maternal breed effects can be interpreted as genetic effects in the dam expressed in her offspring. Grandmaternal breed effects were calculated as the difference in means of traits reported between calves of reciprocal-cross cows. Grandmaternal breed effects are genetic effects in the granddam expressed in her daughter's calves. Numbers of observations for reproductive traits, birth weight, and preweaning traits are given in Table 1.

Table 1. Sample size for grandsire breed × grandam breed × preweaning forage environment for reproductive, birth, and weaning traits

Preweaning forage and trait[a]	A × A[b]	A × B	B × A	B × B
Bermudagrass				
Reproductive	38	46	46	53
Birth	36	46	40	40
Weaning	34	42	38	39
Tall fescue				
Reproductive	27	31	38	57
Birth	15	30	35	37
Weaning	10	29	31	35
Rotation				
Reproductive	55	62	51	44
Birth	52	55	48	35
Weaning	45	52	46	33

[a]Reproductive = calving percentage and weaning weight/cow exposed; Birth = birth weight; Weaning = 205-d weight, hip height, and weight:height ratio.
[b]A = Angus parent or grandparent and B = Brahman parent or grandparent; sire or grandsire breed listed first.

Table 2. Least squares means, heterosis, maternal effects, and standard errors for calving rate (percentage) for cows from bermudagrass, tall fescue, and rotational forage environments

Preweaning environment	Breed group[a] A × A	A × B	B × A	B × B	Mean	Heterosis	Maternal effects
Bermudagrass	93.0 ± 6.5[b]	100.0 ± 6.0[f]	86.8 ± 6.0	75.2 ± 5.6[hi]	88.8 ± 3.1	9.5 ± 5.9[d]	13.6 ± 8.5[f]
Tall fescue	56.4 ± 7.2[c]	93.2 ± 7.1[fg]	87.1 ± 6.5	64.7 ± 5.4[h]	75.3 ± 3.3	29.6 ± 6.5**[e]	6.1 ± 9.6[fg]
Rotation	94.7 ± 5.5[b]	85.0 ± 5.2[g]	92.4 ± 5.7	77.6 ± 6.1[i]	87.4 ± 2.9	2.6 ± 5.5[d]	−7.4 ± 7.7[g]
Mean	81.4 ± 3.9	92.9 ± 3.7	88.8 ± 3.6	72.5 ± 3.4	—	13.9 ± 3.5**	4.1 ± 5.2

[a]A = Angus and B = Brahman; breed of sire listed first.
[b,c]Means in the same column with differing superscripts differ (P < .01).
[d,e]Means in the same column with differing superscripts differ (P < .05).
[f,g]Means in the same column with differing superscripts differ (P < .10).
[h,i]Means in the same column with differing superscripts differ (P = .11).
**P < .01 (H_0: heterosis or maternal effect = 0).

Results and Discussion

Calving Percentage

Calving percentage per cow exposed (**CPE**) is presented in Table 2 for each breed group and forage. Angus cows grazing BG and ROT had 36.6 and 38.3% higher CPE than Angus cows grazing E+ (P < .01), respectively. Angus × Brahman cows on BG had 15% higher CPE than A × B cows on ROT (P < .10), and B × B cows on ROT had 12.9% higher CPE than B × B cows on E+ (P = .11). Heterosis in CPE was important (29.6%, P < .01) on E+ but not significant on BG and ROT (9.5 and 2.6%, respectively). Brown et al. (1997) reported a 13.3% advantage for Angus on BG compared to E+ and that heterosis in Brahman-Angus reciprocal crosses was numerically larger on E+ than on BG. Olson et al. (1993) reported heterosis estimates of 7.6% in crosses of Brahman with Angus for pregnancy rate and 8.0% in crosses of Brahman with Charolais. This was similar to estimates of Koger et al. (1975) for Brahman × Shorthorn crosses for weaning rate. Winder et al. (1992) reported heterosis of 12.0% for weaning rate in Hereford × Brangus crosses. Neville et al. (1984) did not find significant heterosis for calving rate in crosses of Angus, Hereford, and Santa Getrudis. Long (1980), in a summary of crossbreeding results, reported heterosis in calving rate of 6.5 to 9.6% for British × Brahman crosses and 2.4 to 6.7% for British crosses. There was evidence of interaction of maternal effects for CPE with forage in this research (P < .10), with maternal effects in favor of Brahman dams on BG and maternal effects in favor of Angus dams on ROT.

Birth Weight

Least squares means for birth weight are presented in Table 3. Calves from A × A dams were heavier on BG than on E+ (P < .05). Calves from A × B dams were heavier on E+ or ROT than on BG (P < .01). Calves from B × A dams were heavier on ROT than on E+ (P < .10). There was evidence of negative maternal heterosis for birth weight on BG (P < .11) and positive maternal heterosis on ROT and E+ (P < .10), with maternal heterosis interacting with forage (P < .05). Similarly, there was evidence of grandmaternal effects favoring Angus on E+ (P < .01) and Brahman on BG (P < .10). Interactions of grandmaternal effects with forage environment were significant (P < .05). Brown et al. (1997) found little evidence of forage effects on birth weight when comparing BG and E+ but reported favorable maternal heterosis on BG in crosses of Brahman and Angus and grandmaternal effects in favor of Brahman on BG. Olson et al. (1993) reported a 2.9-kg maternal heterosis for birth weight in crosses of Angus and Brahman, but estimates in crosses of Angus and Charolais

Table 3. Least squares means, maternal heterosis, grandmaternal effects, and standard errors for birth weight (kilograms) for calves from bermudagrass, tall fescue, and rotational preweaning environments

Preweaning environment	Breed group[a] A × A	A × B	B × A	B × B	Mean	Maternal heterosis	Grandmaternal
Bermudagrass	40.9 ± 1.7[d]	33.2 ± 2.0[b]	37.4 ± 1.5[fg]	35.0 ± 1.7	36.6 ± 1.0	−2.6 ± 1.6‡[d]	−4.2 ± 2.4†[d]
Tall fescue	34.0 ± 2.9[e]	41.4 ± 2.1[c]	34.8 ± 2.8[f]	33.2 ± 2.0	35.9 ± 1.3	4.5 ± 2.4†[e]	6.6 ± 3.4**[e]
Rotation	39.2 ± 1.4[de]	39.4 ± 1.3[c]	40.8 ± 1.5[g]	35.7 ± 2.0	38.8 ± 0.9	2.6 ± 1.5†[e]	−1.4 ± 1.8[d]
Mean	38.0 ± 1.3	38.0 ± 1.1	37.7 ± 1.2	34.6 ± 1.2	—	1.5 ± 1.1	.3 ± 1.5

[a]A = Angus grandparent and B = Brahman grandparent; breed of grandsire listed first.
[b,c]Means in the same column with differing superscripts differ (P < .01).
[d,e]Means in the same column with differing superscripts differ (P < .05).
[f,g]Means in the same column with differing superscripts differ (P < .10).
‡P < .11, †P < .10, **P < .01 (H_0: maternal heterosis or grandmaternal effect = 0).

Table 4. Least squares means, maternal heterosis, grandmaternal effects, and standard errors for 205-d weight (kg) for calves from bermudagrass, tall fescue, and rotational preweaning environments

Preweaning environment	Breed group[a]				Mean	Maternal heterosis	Grandmaternal
	A × A	A × B	B × A	B × B			
Bermudagrass	221.9 ± 7.2[b]	250.1 ± 7.2[e]	261.8 ± 6.6[g]	249.3 ± 7.2[b]	245.8 ± 5.0	20.4 ± 4.4**[g]	−11.7 ± 8.4
Tall fescue	171.1 ± 12.2[c]	226.8 ± 8.6[f]	231.4 ± 9.2[h]	223.1 ± 8.2[c]	213.1 ± 7.3	32.0 ± 6.0**[h]	−4.5 ± 9.5
Rotation	197.9 ± 6.4[d]	246.1 ± 5.9[e]	248.5 ± 6.5[i]	238.4 ± 7.6[bc]	232.7 ± 4.6	29.2 ± 4.3**[gh]	−2.3 ± 7.8
Mean	197.0 ± 6.4	241.0 ± 5.2	247.2 ± 5.4	236.9 ± 5.5	—	27.2 ± 2.9**	−6.2 ± 6.9

[a]A = Angus grandparent and B = Brahman grandparent; breed of grandsire listed first.
[b,c,d]Means in the same column with differing superscripts differ ($P < .01$).
[e,f]Means in the same column with differing superscripts differ ($P < .05$).
[g,h,i]Means in the same column with differing superscripts differ ($P < .10$).
**$P < .01$ (H_0: maternal heterosis or grandmaternal effect = 0).

and Brahman and Charolais were not significant. Sacco et al. (1989) did not find significant maternal heterosis for birth weight in Brahman × British crosses. Dearborn et al. (1987) reported maternal heterosis estimates for birth weights in crosses among Red Poll, Brown Swiss, Hereford, and Angus ranging from 1.4 to .5 kg.

205-Day Weight

Least squares means for 205-d weight are given in Table 4. There was evidence of forage effects in 205-d weight in A × A and B × B ($P < .01$), A × B ($P < .05$), and B × A ($P < .10$). Additionally, we observed maternal heterosis for this trait ($P < .01$) on all forages. Maternal heterosis for 205-d weight was larger on E+ than on BG ($P < .10$). There was little evidence of grandmaternal effects. Brown et al. (1997) reported significantly greater maternal heterosis in 205-d weight in calves from Brahman and Angus crosses on E+ than on BG. Estimates of maternal heterosis for weaning weight in crosses of Brahman with Charolais and Angus reported by Olson et al. (1993) were similar to estimates from this research on BG but were smaller than estimates on E+ and ROT. Long (1980) reported estimates of maternal heterosis in weaning weight from Brahman × British crosses ranging from 13.8 to 29.0 kg, and estimates for British crosses ranged from 7.0 to 10.0 kg. Sacco et al. (1989) reported maternal heterosis for weaning weight of 17.6 and 27.7 kg for calves from crosses of Brahman with Angus and Hereford, respectively. Koger et al. (1975) reported levels of maternal heterosis in calves from crosses of Brahman and Shorthorn similar to those observed by Olson et al. (1993).

Thus, results from this research lead us to conclude that Brahman-Angus F_1 crossbreds and their calves were more tolerant of negative effects of E+ environment, whether managed all year or managed in a rotational scheme with BG.

Weaning Hip Height

Least squares means for weaning hip height are given in Table 5. Calves from A × A cows on BG and ROT exceeded those on E+ ($P < .05$); calves from A × B and B × A cows on ROT exceeded those on BG and E+ ($P < .05$); and calves from B × B on ROT exceeded those on BG ($P < .10$). Maternal heterosis for this trait was important for all forages ($P < .01$ for E+ and ROT; $P < .10$ for BG) but greater on E+ and ROT than on BG ($P < .01$). Grandmaternal effects were not evident on any forage. Brown et al. (1997) reported significantly greater maternal heterosis in hip height for calves from crosses of Brahman and Angus on E+ than on BG. Sacco et al. (1989) reported maternal heterosis for weaning hip height of 1.8 and 2.7 cm for calves from crosses of Brahman with Angus and Hereford, respectively.

Table 5. Least squares means, maternal heterosis, grandmaternal effects, and standard errors for weaning hip height (cm) for calves from bermudagrass, tall fescue, and rotational preweaning environments

Preweaning environment	Breed group[a]				Mean	Maternal heterosis	Grandmaternal
	A × A	A × B	B × A	B × B			
Bermudagrass	110.5 ± 1.3[d]	114.7 ± 1.3[d]	116.0 ± 1.2[d]	117.4 ± 1.3[f]	114.6 ± .9	1.4 ± .8†[b]	−1.2 ± 1.5
Tall fescue	105.0 ± 2.2[e]	116.3 ± 1.5[d]	115.9 ± 1.6[d]	117.8 ± 1.5[fg]	113.8 ± 1.3	4.7 ± 1.1**[c]	.44 ± 1.7
Rotation	111.6 ± 1.1[d]	120.1 ± 1.1[e]	120.5 ± 1.2[e]	120.3 ± 1.4[g]	118.2 ± .8	4.3 ± .8**[c]	−.44 ± 1.4
Mean	109.0 ± 1.1	117.1 ± .9	117.5 ± 1.0	118.5 ± 1.0	—	3.5 ± .5**	−.41 ± 1.2

[a]A = Angus grandparent and B = Brahman grandparent; breed of grandsire listed first.
[b,c]Means in the same column with differing superscripts differ ($P < .01$).
[d,e]Means in the same column with differing superscripts differ ($P < .05$).
[f,g]Means in the same column with differing superscripts differ ($P < .10$).
†$P < .10$, **$P < .01$ (H_0: maternal heterosis or grandmaternal effect = 0).

Table 6. Least squares means, maternal heterosis, grandmaternal effects, and standard errors for weight:height ratio (kg/cm) for calves from bermudagrass, tall fescue, and rotational preweaning environments

Preweaning environment	Breed group[a] A × A	A × B	B × A	B × B	Mean	Maternal heterosis	Grandmaternal
Bermudagrass	2.01 ± .05[d]	2.17 ± .05[b]	2.25 ± .05[b]	2.12 ± .05[d]	2.14 ± .03	.15 ± .03**	–.07 ± .06
Tall fescue	1.62 ± .09[e]	1.94 ± .06[c]	1.99 ± .06[c]	1.89 ± .06[e]	1.86 ± .05	.21 ± .04**	–.04 ± .07
Rotation	1.77 ± .04[f]	2.04 ± .04[c]	2.06 ± .05[c]	1.98 ± .05[e]	1.96 ± .03	.18 ± .03**	–.02 ± .05
Mean	1.80 ± .04	2.05 ± .04	2.10 ± .04	2.00 ± .04	—	.18 ± .02**	–.05 ± .05

[a]A = Angus grandparent and B = Brahman grandparent; breed of grandsire listed first.
[b,c]Means in the same column with differing superscripts differ ($P < .01$).
[d,e,f]Means in the same column with differing superscripts differ ($P < .05$).
**$P < .01$ (H_0: maternal heterosis or grandmaternal effect = 0).

Weaning Weight:Height Ratio

Least squares means for weaning weight:hip height ratio are given in Table 6. Calves from A × A on BG exceeded those on ROT and E+ ($P < .01$), and calves from A × A on ROT exceeded those on E+ ($P < .05$). Calves from A × B, B × A, and B × B on BG exceeded contemporary calves on E+ and ROT ($P < .05$). Maternal heterosis for weight:height ratio was important ($P < .01$) and similar among forages. There was little evidence of grandmaternal effects for any forage. Estimates of maternal heterosis for this ratio for calves from Brahman and Angus crosses reported by Brown et al. (1997) were greater in calves managed on E+ than in calves on BG. Olson et al. (1993) reported substantial maternal heterosis for weaning condition score in calves from crosses of Brahman with Angus and Charolais, but estimates in crosses of Angus and Charolais were smaller. Koger et al. (1975) reported maternal heterosis for weaning condition score in calves from Brahman × Shorthorn crosses similar to those reported by Olson et al. (1993).

Weaning Weight per Cow Exposed

The combination of reproductive and maternal performance of the cow and growth of the calf is reflected in weaning weight per cow exposed (Table 7). Heterosis for this trait was important ($P < .01$) and was greater on E+ than on BG and ROT ($P < .01$). On BG and ROT, crossbred cows weaned 44.7 and 50.9 kg ($P < .01$) more calf per cow exposed, respectively, than did purebred cows, and crossbred cows on E+ weaned 125.8 kg ($P < .01$) more calf per cow exposed than did purebreds. Again, in this trait, tolerance by the crossbred cows and their calves to endophyte-infected fescue is suggested. Heterosis for 205-d weight per cow exposed reported by Brown et al. (1997) was numerically higher in Brahman-Angus crosses on E+ than in contemporaries on BG. Winder et al. (1992) reported heterosis of 34.6 kg in weaning weight per year. Koger et al. (1975) reported heterosis of 46.1 kg in annual production per cow in Brahman × British crosses, and Dearborn et al. (1987) reported values ranging from –4.7 to 35.9 kg in crosses among Red Poll, Brown Swiss, Hereford, and Angus.

Implications

Brahman × Angus or Angus × Brahman crossbred cows demonstrate tolerance to endophyte-infected tall fescue and may be useful in management of the deleterious effects of this forage on cattle productivity. Rotating cows and calves from endophyte-infected tall fescue to common bermudagrass in the summer can moderate some, but not all, of the effects of endophyte-infected tall fescue on calf growth. The effect of rotation between endophyte-infected tall fescue and common bermudagrass on reproductive traits was more beneficial for

Table 7. Least squares means, heterosis, maternal effects, and standard errors for weaning weight per cow exposed (kg) for cows from bermudagrass, tall fescue, and rotational forage environments

Preweaning environment	Breed group[a] A × A	A × B	B × A	B × B	Mean	Heterosis	Maternal effects
Bermudagrass	221.4 ± 20.0[b]	263.8 ± 18.8[f]	233.9 ± 18.1	186.9 ± 17.2[d]	226.5 ± 10.0	44.7 ± 16.8**[b]	29.9 ± 26.1
Tall fescue	74.5 ± 23.4[c]	241.8 ± 21.9[fg]	220.9 ± 20.0	136.6 ± 16.9[e]	168.4 ± 10.9	125.8 ± 19.6**[c]	21.0 ± 29.7
Rotation	183.9 ± 17.5[b]	228.1 ± 16.5[g]	241.6 ± 17.5	184.0 ± 18.7[d]	209.4 ± 9.6	50.9 ± 15.7**[b]	–13.5 ± 24.1
Mean	159.9 ± 13.6	244.6 ± 13.0	232.1 ± 12.2	169.1 ± 11.6	—	73.8 ± 10.1**	12.5 ± 17.8

[a]A = Angus and B = Brahman; breed of sire listed first.
[b,c]Means in the same column with differing superscripts ($P < .01$).
[d,e]Means in the same column with differing superscripts differ ($P < .05$).
[f,g]Means in the same column with differing superscripts differ ($P < .11$).
**$P < .01$ (H_0: heterosis or maternal effect = 0).

purebred cows than for crossbred cows. Although this technology does not eliminate production losses attributable to endophyte-infected tall fescue, it seems to reduce these losses. In combination with other technologies available for the management of endophyte-infected tall fescue, it may be possible to reduce losses to more acceptable levels.

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