ESTIMATION OF GENETIC PARAMETERS FOR POST-WEANING PERFORMANCE TRAITS IN BRAHMAN AND BRAHMAN-INFLUENCED STOCKER CATTLE ON FORAGE-BASED STUDIES

A Thesis

by

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ABSTRACT

The objectives of this study were to estimate heritability of performance traits in Brahman and Brahman-influenced (¼ or ½ Brahman) stocker cattle on cool-season (n = 1,732) and warm-season (n = 1,199) forages. Cattle were born from 1986 to 2011 at the Texas A&M AgriLife Research and Extension Center at Overton, TX. Traits included end of period body weight (BW), average daily gain (ADG), and body condition score (BCS). Data were analyzed for each season using animal models, with main effects including stocking rate (3 levels), breed type (3 levels), supplementation (2 levels), and contemporary groups constructed by sex and year. Age was fit as a linear covariate.

Across levels of stocking rate, calves at low stocking rates had heavier BW, higher ADG, and higher BCS than calves at medium and high stocking rates. For cool-season ADG and BCS, an interaction between breed type and supplementation was included ($P = 0.002$). Supplemented calves had higher BCS across all breed types, while only ¼ Brahman ADG was greater for supplemented cattle. All warm-season traits differed between levels of supplementation. For warm-season, ¼ Brahman had the heaviest BW, while ½ and purebred Brahman did not differ ($P = 0.39$). For ADG, ½ Brahman was greater than ¼ Brahmans and purebreds, which did not differ ($P = 0.10$). No difference in warm-season BCS between breed types was detected. Heritability estimates for cool-season BW, ADG, and BCS were 0.72 ± 0.094, 0.14 ± 0.083, and 0.25 ± 0.099, respectively. For warm-season forages, heritability estimates for BW, ADG, and BCS were 0.44 ± 0.130, 0.15 ± 0.099, and 0.29 ± 0.106, respectively. The

estimates for ADG and BCS in both seasons corresponded with estimates of similar traits in other experiments, as did the estimate for warm-season BW. The estimate for cool-season BW seemed high. Potential causes included influence of breed type on heritability estimates, as documented in other studies, as well as differences between traits in seasons, where measurements of the same trait in different environments could differ.

DEDICATION

To my family: for believing in me when I doubted myself.

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Finally, I want to thank The Lord for His love and all the blessings in my life. I've been given much, and I hope to give back as much as I can from here on out.

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CHAPTER I

INTRODUCTION

Brahman and Brahman-influenced cattle are responsible for a prominent share of the Texas and Gulf Coast beef cattle industry. Tolerance of hot, humid conditions and resistance to parasites and disease allow these cattle to thrive in environmental conditions in which other popular breeds of beef cattle do not perform as well (Hammond et al., 1998). The mating of Brahman with *Bos taurus* breeds of cattle has resulted in crossbred cattle that combine the carcass characteristics of *Bos taurus* cattle with the heat tolerance and hardiness of *Bos indicus* breeds to produce commercial cattle that are biologically and economically successful in the Southwest region of the United States.

As input costs increase for cattle feeders, the industry continues to utilize post-weaning grazing of available forages as a cost-effective method of adding gains to stocker calves (Brown et al., 1999). The most common measure of performance in stocker cattle is average daily gain (ADG). Genetic parameters have been estimated for post-weaning gain in various experiments. Estimates of genetic parameters for performance traits can be valuable in breeding programs for improvement of post-weaning performance in stocker cattle. However, most of the studies in the United States utilized *Bos taurus* breed type cattle.

The primary objective of this study was to estimate genetic parameters of post-weaning growth traits, such as ADG, body condition score (BCS), and body weight

(BW), specifically in Brahman and Brahman-influenced calves on stocker grazing experiments. Additionally, estimates of genetic parameters of growth traits in the same cattle were obtained from distinct analyses by season of grazing. Finally, utilizing the same population of *Bos indicus*-influenced cattle, heritability of ADG, BCS, and body weight on stocker cattle was investigated, grouping cattle by the primary forage grazed. Stocking season and forage type were confounded, therefore analyzing by forage type was not beneficial and was omitted from the study.

CHAPTER II

LITERATURE REVIEW

Genetic parameters of post-weaning gain in **Bos taurus** *cattle in the United States*

Koch et al. (1982) estimated heritability of post-weaning gain for 2,410 crossbred steers, from the USDA Germ Plasm Evaluation program, as well as 3,088 Hereford bulls at the Roman L. Hruska U.S. Meat Animal Research Center. Over a 224-d post-weaning period, heritability of gain was estimated in 28-d intervals, as well as estimates across all possible intervals within the period. For the crossbred steers, heritability estimates ranged from 0.16 ± 0.08 for 28-d periods to 0.55 ± 0.08 for the 224-d period. Heritability of gain for the Hereford bulls ranged from 0.08 ± 0.06 for 28 d to 0.24 ± 0.06 for the 224-d period. Estimates increased as length of period increased due to decreases in genetic and environmental deviations from the linear regression.

Heritability of post-weaning gain on forage in **Bos indicus** *cattle in Australia*

Seifert (1975) estimated heritability for post-weaning gain in F_2 Brahman-Hereford and Brahman-Shorthorn, as well as F_2 Africander-Hereford and Africander-Shorthorn calves. An additional adjustment for age and year of birth of the dam was used in a second heritability estimation. When taking into account the age of dam effects and the year of birth of the dam, estimated heritability was 0.327. Not including age of dam effects, the estimate was 0.087.

Genetic parameters were estimated in steers and heifers of Brahman descent, as well as a tropically-adapted composite, comprised of ½ *Bos indicus* or tropically adapted *Bos taurus* (African Sanga), and ½ non-tropically adapted *Bos taurus* (Barwick et al., 2009a and 2009b). These cattle were descendants of the cattle used in the Seifert (1975) experiment and were produced by inter se mating. Several cooperating herds were employed to produce the cattle used in these studies. Heifers were evaluated for growth traits at the end of post-weaning during the wet or dry season (Barwick et al., 2009a). After weaning, heifers were transferred to one of four locations to be developed. Measurements were taken at regular intervals post-weaning, reporting at the end of the first wet season (1 June) and the second dry season (1 December), corresponding to approximately 18 and 24 mo of age. The estimate of genetic correlation between dry season ADG and wet season ADG was positive and moderate (0.33 ± 0.18). Estimates of heritability of ADG for wet seasons were 0.25 ± 0.09 for Brahman and 0.39 ± 0.11 for composites. At the end of the dry season, estimates of heritability were 0.14 ± 0.06 for Brahman and 0.18 ± 0.07 for the composite females.

Barwick et al. (2009b) also estimated genetic parameters for steers of the same breed types as the heifers mentioned previously. Estimates of heritability for ADG during the post-weaning period, with calves being weaned around 6.5 mo of age, until entry into the feedlot were 0.18 ± 0.08 and 0.30 ± 0.09, respectively, for Brahman and tropical composite cattle. There was essentially no genetic correlation between rate of gain on pasture and rate of gain in the feedlot in Brahman (0.10 ± 0.27). The estimate for tropical composite steers was large and positive (0.64 ± 0.15). The estimate of genetic correlation from analyses that combined steers of both breed types was 0.42 ± 0.14. The low correlation in Brahman corresponds with previous estimates that demonstrated low correlations between gains at different times in *Bos indicus* cattle (Mackinnon et al. 1991; Robinson and O'Rourke 1992; Davis, 1993). Results suggested that gains at different time periods should be considered separate traits in genetic evaluations. A higher genetic correlation was detected for traits at the end of the two grazing seasons in heifers compared to entry and exit of the feedlot in steers.

Heritability of post-weaning gain on forage in* Bos indicus *cattle in South America

Cardoso and Templeman (2004) used Bayesian analysis of a multi-breed animal model to estimate heritability of post-weaning gain in a population of 22,717 Hereford, Nellore, and Hereford-Nellore crossbred cattle raised under extensive pasture conditions as part of a large scale Brazilian breeding program. The heritability estimate for Nellore cattle was 0.07 ± 0.02, and that for F_1 cattle was 0.14 ± 0.02. Using the same data in a conventional animal model, an estimate of 0.15 ± 0.02 was found.

Toral et al. (2011) estimated heritability of post-weaning ADG in Hereford and Hereford-Nellore crossbred cattle. Cattle in this study were part of the same breeding program used in the Cardoso and Templeman (2004) experiment. Records of post-weaning ADG on 45,773 animals raised on 47 different ranches in Brazil were used. The types of cattle included purebred Hereford, as well Hereford-Nellore crosses that were comprised of ¼ to ¾ Hereford breeding. The heritability estimate reported in this study was low (0.164 ± 0.013).

Heritability of post-weaning gain from records for 49,267 Nellore cattle was estimated by Caetano et al. (2013) as part of the Nellore Cattle Breeding Program of the Association of Breeders and Researchers in Brazil. Estimates were done as part of an analysis of economically important traits. The heritability estimate for rate of gain from weaning at 210 d until a year of age was 0.163 ± 0.011.

As part of a pasture-based bull testing program in Brazil from 2004 to 2010, weights and visual scores were collected on 21,032 Nellore bulls (Lima et al., 2013). Starting at approximately one year of age, bulls were on pasture test for 224 d. Heritability was estimated for final weight, weight gain, and adjusted 550-d weight, in addition to traits considered part of the standardized visual appraisal system used in Brazilian breeding programs. Estimates of heritability for weight gain (0.26 ± 0.02), final weight (0.50 ± 0.03), and adjusted 550-d weight (0.46 ± 0.04) showed that change can be made when selecting for these traits. Moderate to high genetic and phenotypic correlations were found between weight and growth traits recorded in this study. Results are displayed in Table 1.

Table 1. Estimates of heritability for post-weaning grazing ADG in *Bos indicus and Bos indicus*-influenced cattle

Study	Breed type	N	Heritability ± SE
Koch et al., 1982	Hereford (224-d period)	3,308	0.24 ± 0.06
	Crossbred (224-d period)	2,410	0.55 ± 0.08
Seifert 1975	F_2 Africander/Brahman x British (dam effects included)	175	0.33 ± 0.05
	F_2 Africander/Brahman x British (dam effects excluded)	175	0.09± 0.05
Barwick et al., 2009a (heifers)	Brahman (wet season)	1,027	0.25 ± 0.09
	Tropical Composite (wet season)	1,132	0.39 ± 0.11
	Brahman (dry season)	1,027	0.14 ± 0.06
	Tropical Composite (dry season)	1,132	0.18 ± 0.07
Barwick et al., 2009b (steers)	Brahman	1,007	0.18 ± 0.08
	Tropical Composite	1,209	0.30 ± 0.09
Toral et al., 2011	Hereford, Hereford-Nellore	45,773	0.16 ± 0.01
Cardoso and Templeman, 2004	Nellore	91	0.07 ± 0.02
	F_1 Hereford x Nellore and Nellore x Hereford	8,718	0.14 ± 0.02
Caetano et al., 2013	Nellore	49,267	0.16 ± 0.01
Lima et al., 2013	Nellore	21,032	0.26 ± 0.02

Genetic parameters for growth in Brahman and Brahman derivative cattle

Data were collected from national cattle evaluations to estimate additive and maternal heritability for birth weight and weaning weight, as well as additive heritability for post-weaning growth in Brahman, Beefmaster, Brangus, and Santa Gertrudis cattle (Kriese et al., 1991). Adjusted birth weight, 205-d weights, and 365-d weights were evaluated for each breed, with post-weaning gain defined as the difference between 365- and 205-d weights. Weaning contemporary groups were formed using herd, sex, use of creep feed, and weaning date. Post-weaning gain and birth weight records were assigned to their weaning group in order to simplify the variance component analyses, as both traits were assumed to be defined by the same contemporary group, or simply a subset of the other traits (Kriese et al., 1991). Estimates for adjusted post-weaning heritability are presented in Table 2. Estimates ranged from 0.15 (Brangus) to 0.56 (Beefmaster). However, these estimates were in accordance with a wide range of estimates in previous work (Woldehawariat et al., 1977; Garrick et al., 1989). Large positive genetic correlations were found between weaning weight and post-weaning gain in each breed except Santa Gertrudis, which had a small negative correlation. The author attributed the negative correlation to small sample size and selection bias. Environmental correlations between weaning weight and post-weaning gain were negative for all 4 breeds and were possibly due to compensatory gain effects.

Table 2. Heritability of weaning weight and post-weaning gain in Brahman and derivative breeds from NCE data

Breed	N	Trait	Heritability
Brahman	12,559	Weaning wt (additive)	0.23
	3,565	Post-weaning gain	0.31
Beefmaster	7,211	Weaning wt (additive)	0.50
	1,576	Post-weaning gain	0.56
Brangus	58,932	Weaning wt (additive)	0.21
	16,456	Post-weaning gain	0.15
Santa Gertrudis	23,180	Weaning wt (additive)	0.25
	2,868	Post-weaning gain	0.26

[1] Kriese et al., 1991

Genetic parameter estimates of gain in* Bos indicus *influenced cattle in U.S. feedlot settings

Estimates of heritability for rate of gain in *Bos indicus* cattle have been reported in experiments using various methods and experimental designs. Warwick and Cartwright (1955) estimated heritability of gain on feed test of 853 head of Brahman, Hereford, and F_1 bulls, heifers, and steers from 1949 to 1953 at the Texas Agricultural Experiment Station at McGregor, TX. In an effort to remove the effects of year, sex, and ration, the ratio of rate of gain (animal's rate of gain/average rate of gain for the contemporary group) was used for estimates instead of the recorded gain data. Two methods were used to estimate heritability: 1) correlation between half-siblings; and 2) regression of offspring on parent. For the 124 Brahman on feed tests, estimated heritability of ratio of rate of gain was 0.46 using correlation between half-siblings, while the Hereford × Brahman F_1 estimate was 0.33. The heritability estimate of all animals on feed test, including Hereford, was 0.38. The regression of offspring on parent resulted in an estimated heritability of 0.57, which included Hereford, Brahman and F_1 animals. Estimates using rate of gain ratio were lower than estimates using recorded gain data, and recorded gain data had more variation in estimates. Warwick and Cartwright (1955) acknowledged that using the ratio did not produce true estimates of heritability, but could perhaps be more useful for selection. If replacements were annually selected for maximum rate of gain, using ratios eliminated breed and year differences in the comparisons. In addition, ratios allowed for comparison of sire's progeny across the duration of the tests.

Riley et al. (2002) estimated heritability for carcass traits in purebred Brahman using a sample of 504 animals which included 246 steers and 258 heifers from the USDA Subtropical Agricultural Research Station near Brooksville, FL. After weaning, calves were placed in a preconditioning program for 2- to 3-weeks before entering the feedlot. After median backfat for a pen reached 10 mm, cattle were harvested at a local facility. An estimated heritability for ADG in the feedlot of 0.64 was reported, which was higher than previous estimates reported in literature. For harvest weight, the reported heritability estimate of 0.47 was higher than previously published estimates in various types and crosses of *Bos taurus* cattle.

A study was conducted of 467 purebred Brahman steer calves raised in Louisiana from 1996 to 2000 that were purchased and placed into a ryegrass (*Lolium multiflorum)* stocker program at a central location in Louisiana, before being finished in a South Texas feedlot and harvested in a commercial plant in the same region (Smith et al., 2007). Traits evaluated included growth, carcass, and palatability traits, with heritability estimated for traits such as ADG during the feedlot phase, harvest body weight, hot carcass weight, longissimus muscle area, marbling, quality grade, and yield grade. The heritability estimate for ADG in the feedlot (0.33 ± 0.14) was similar to previous estimates of the same trait in purebred and composite *Bos taurus* cattle (0.36 ± 0.09), as reported by Gregory et al. (1995). The estimate of heritability for body weight at harvest was considered to be high (0.59 ± 0.16), but was comparable to estimates of 0.52 ± 0.14 reported by Koots et al. (1994), as well as the estimate reported by Riley et al. (2002), as presented in Table 3. The estimates came from studies with relatively small sample sizes. More records in each experiment would produce estimates of heritability with lower standard errors.

In a feeding experiment with 468 Brangus heifers, phenotypic and genetic relationships between and among ultrasound carcass traits and performance traits were evaluated (Lancaster et al., 2009). Heifers were on a roughage-based diet for 70 d, with individual feed intake being measured weekly by a GrowSafe feeding system. The estimate for heritability of ADG was calculated as 0.21 ± 0.12. Average daily gain had a high genetic correlation estimate with mid-test body weight (0.99 ± 0.08) and dry matter intake (0.56 ± 0.22), as well as phenotypic correlations with mid-test body weight of 0.35 and dry matter intake of 0.57. It is important to consider that these estimates were made based on a short-term feeding experiments emphasizing feed intake, while others previously cited (Riley et al, 2002; Smith et al., 2007) estimated heritability from feeding experiments that were carried out until the animals were harvested.

Table 3. Estimates of heritability for feedlot performance traits in U.S. *Bos indicus* cattle

Study	Breed type	Trait	N	Heritability ± SE
Warwick and Cartwright, 1955	Brahman	ADG	124	0.46
	Hereford × Brahman		359	0.33
	All animals		871	0.38
Riley et al., 2002	Brahman	ADG	504	0.64
		Harvest BW	504	0.47
Smith et al., 2007	Brahman	ADG	430	0.33 ± 0.14
		Harvest BW	430	0.59 ± 0.16
Lancaster et al., 2009	Brangus	ADG	468	0.21 ± 0.12

Comparison of effects of forage type and management on performance in **Bos indicus** *stockers*

Management of growing cattle grazing on pasture involves multiple variables that can affect individual animal performance. Additional weight gain increases the profit of growing cattle, as long as costs of additional gain are less than the generated value. Type and quality of forage, stocking rate, and supplemental feeding are all factors that must be managed properly in order to achieve maximum profitability with a set of stocker cattle. The effects of management on individual performance are important to consider in a study of genetic parameter estimation due to the fact that all animals may not be in the same environment. Additionally, performance varies in different seasons, largely due to nutritive value of forages. Differences in forage nutritive value must be taken into consideration, especially with *Bos indicus*-influenced cattle.

The effects of practices prior to and after weaning on performance of cattle in later phases of production were analyzed by Phillips et al. (1991). Calves sired by Braford bulls and out of Brahman × Hereford F_1 cows, from 1986 to 1988 were raised in four systems of varying grazing pressure, ranging from low pressure to high pressure, in Uvalde, TX. One hundred seventeen steers and heifers were transported to El Reno, OK post-weaning, where they were randomly blocked into one of two post-weaning grazing experiments. One experiment was carried out on dormant native forage, primarily little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), and Indiangrass (*Sorghastrum nutans*) stocked at a rate of 1.7 ha per animal. The steers in the other experiment grazed wheat (*Triticum aestivum*) pasture at a rate of 0.4 to 1.0 ha per animal, with the objective being for calves to gain twice as much as those on native forage. At the end of the winter stocking phase, all cattle were managed as a single group for the spring grazing. Cattle grazed winter pasture for an average of 55 d, followed by an average of 42 d on bermudagrass (*Cyndon dactylon)* pasture. The pre-weaning grazing pressure at which calves were raised had no detectable effect on performance of cattle in either the native forage or winter wheat treatment of the winter grazing. As expected, rates of gain of the cattle in the wheat group were at least twice that of the calves in the native forage group in each of the three years. During spring grazing, cattle grazing native pasture had greater rates of gain than cattle in the winter wheat groups in two of the three years, which was due in large part to compensatory gain. Across the entire grazing period, wheat grazing calves had higher gains than cattle on native forage.

Sharman et al. (2013) examined the differences in carcass characteristics of Angus steers in different stocker environments. A sample of 73 steers were stratified by body weight and sire into one of four grazing treatments: 1) dormant native range grasses with a protein supplement; 2) corn/soybean meal supplement while grazing dormant native range; 3) wheat pasture at a high stocking rate (3.21 steers/ha) to achieve low body weight gain; and 4) wheat pasture at low stocking rate (0.99 steers/ha) to achieve high body weight gain. At the end of the 138-d grazing period, ADG for each treatment was different and ranged from 0.19 kg/d for the control group to 1.37 kg/d in the low stocked wheat group.

Brown et al. (1999) evaluated differences in performance of 403 Polled Hereford-sired calves from Angus, Brahman, and reciprocal cross dams that were raised in either endophyte-infected tall fescue (*Festuca arundinaceia*) or bermudagrass pasture during pre-weaning. At weaning, calves raised on bermudagrass pastures from each of the four types of dams had a greater body weight than those raised on the tall fescue pastures by approximately of 37.1 kg. During the winter stocking phase, differences in ADG between pre-weaning treatments occurred for calves out of Angus dams and Brahman × Angus dams. Averaged across all breed groups, the post-weaning average gains of calves raised on tall fescue (0.41 ± 0.01 kg) were higher than those raised on bermudagrass (0.36 ± 0.01 kg). Calves from the fescue treatments exhibited compensatory gain during the initial stocker phase. From the end of the winter stocker period in March until entering the feedlot in June, calves grazed cool-season forages. No differences occurred during the spring grazing which was likely due to all calves grazing the same pasture during this period.

The same calves used by Brown et al. (1999) were evaluated for performance differences based on winter stocker treatment (Phillips et al., 2001). After weaning, calves were placed on either winter wheat pasture or native prairie pasture for the winter stocker period. Calves in the winter wheat group had greater ADG than those in the native pasture groups during the winter phase. There was no difference between groups in the spring phase as they were all grazing the same cool-season forages in a single pasture.

Purebred Brahman steers, as well as F_1 Angus × Brahman and F_1 Tuli × Brahman steers, were randomly assigned to a winter pasture location (Overton, TX or El Reno, OK) (Rouquette et al., 1996). Steers at Overton grazed ryegrass pastures, while steers in El Reno grazed wheat pastures. In both locations, Angus × Brahman steers had the highest ADG, while purebred Brahman steers had the lowest ADG. However, the difference between ADG in Tuli × Brahman and purebred Brahman was greater at El Reno than at Overton.

Brahman × Hereford heifers were assigned to grazing pastures consisting of varieties of bermudagrass overseeded with ryegrass and arrowleaf clover (*Trifolium vesiculosum*) at Overton, TX, or native range pasture at Uvalde, TX (Rouquette et al., 1986). At both locations, four levels of grazing pressure were implemented. At Overton, ADG ranged from 0.94 to 1.70 lb/d across levels of grazing pressure. At

Uvalde, ADG ranged from 1.03 to 1.29 lb/d across levels of grazing pressure. Gain per animal and gain per acre were both greater at Overton, as was forage production per acre.

Grigsby et al. (1989) conducted experiments in 1986 and 1987 to determine the influence of source and level of self-limiting protein supplements on performance of weaned, fall-born ½ Simmental × ¼ Brahman × ¼ Hereford calves grazing bermudagrass pastures. Treatments in Year 1 included bermudagrass pasture, bermudagrass pasture with a commercial molasses block, bermudagrass pasture with a molasses block containing fishmeal, bermudagrass pasture plus a dry protein supplement, bermudagrass pasture with a dry protein supplement plus rumen-stable lysine and methionine, and bermudagrass pasture plus a fishmeal and Rumensin (Elanco, Greenfield, IN, USA) supplement. Year 2 treatments included a control group on bermudagrass pasture, and treatments of bermudagrass pasture with additional supplements including commercial molasses blocks, as well as commercial molasses blocks containing fishmeal, a dry protein supplement containing soybean meal, fishmeal, and monensin, a dry protein supplement containing fishmeal, and a dry protein supplement containing fishmeal and monensin. Seventy two calves were equally divided into each of the six treatments in Year 1. The ADG with the molasses block including fishmeal was greater than all other treatments. All treatments resulted in calves being in lighter condition at the end of the period than at the beginning. In Year 2, 70 calves were allotted by weight to the five treatments. The ADG of calves receiving supplement was greater than those on non-supplemented pasture.

Grigsby et al. (1991) also conducted a two year experiment to investigate the effects of various self-limiting supplementation strategies on gain and intake on weaned ½ Simmental × ¼ Hereford × ¼ Brahman steer and heifer calves grazing ryegrass pasture. In Year 1, 40 animals were assigned by weight and body condition to one of four groups: ryegrass pasture with free choice mineral, ryegrass pasture plus a fishmeal supplement, ryegrass pasture plus a corn supplement, and ryegrass pasture plus a corn supplement containing rumen-stable lysine and methionine. In Year 2, 30 calves were randomly assigned to a ryegrass control pasture, pasture with fishmeal supplement, or pasture with corn supplementation. Results showed that calves in all of the treatments with a corn supplement had higher ADG than calves on fishmeal or pasture-only treatments. Calves receiving corn consumed a greater amount of supplement than calves in fishmeal treatments. Higher gains on corn supplement were possibly due to the increased consumption of corn.

Brahman heifers were assigned to one of three pasture treatments: 1) Coastal bermudagrass hay plus corn and fish meal supplementation; 2) rye-ryegrass overseeded on Coastal bermudagrass sod; and 3) the same type pasture as treatment 2 with the addition of corn and fish meal supplementation (Rocha et al., 1994). Across treatments, heifers on the supplemented rye-ryegrass pasture had the greatest ADG, while heifers receiving hay and supplementation had the lowest ADG.

Steers and heifers sired by Hereford bulls from Angus × Brahman F_1 dams were assigned to grazing pastures consisting of Tifton-85 bermudagrass or Coastal bermudagrass to analyze ADG (Rouquette et al., 2002a). Calves grazing Coastal bermudagrass were fed an additional corn and soybean meal supplemental ration. While ADG of calves on both forages were comparable, the greater stocking rate on Tifton-85 resulted in gains per acre over twice as great as those on Coastal.

Rouquette et al. (2002b) evaluated growth rate in calves of various breed types under two stocking rates (low and high) imposed on each of three stocking methods, including continuous, 8-paddock rotational, and 16-paddock rotational. Across all breed types, differences in ADG were detected for levels of stocking rate, as well as stocking method. Continuous grazing systems had greater ADG than rotational systems across both levels of stocking rate. Calves with ¼ *Bos indicus* breeding had greater ADG than calves with ½ *Bos indicus* breeding at both levels of stocking rate.

Rouquette et al. (2010) investigated the differences in ADG of ½ Simmental × ¼ Angus × ¼ Hereford calves grazing Tifton 85 bermudagrass at three levels of stocking rate (low, medium, and high). Each level of stocking rate had treatments of calves grazing pasture only and calves receiving 0.4% of body weight of a soybean meal and corn supplemental ration. At each level of stocking rate, ADG was greater for supplemented calves than calves that were part of pasture only treatments.

CHAPTER III

MATERIALS AND METHODS

Data collection

Cattle for the experiments were born at the Texas A&M AgriLife Research & Extension Center at Overton, TX between 1986 and 2011. Purebred Brahman cows were mated to produce purebred and crossbred offspring. Brahman cows were bred to Hereford, Angus, Romosinuano, or Tuli bulls to create F_1 offspring. Selected heifers from the F_1 generation were mated primarily to Simmental bulls, but also Angus, Hereford, Bonsmara, and Romosinuano bulls, which resulted in calves that were ¼ Brahman. Cattle in the analysis were classified according to proportion of Brahman lineage. Classifications included ¼ Brahman, ½ Brahman, and purebred Brahmans.

Sire and dam pedigree information was recorded as available on both Brahman and Brahman-cross calves. Due to the use of multiple-sire breeding pastures, individual sire information was not available on calves from crossbred dams. Table 4 shows the number of records available by breed type and season of grazing.

Table 4. Number of records by breed type, sex, and grazing season

Breed type	Cool-season	Warm-season
¼ Brahman	N	N
Steers	601	375
Heifers	516	399
½ Brahman		
Steers	161	35
Heifers	38	4
Brahman		
Steers	247	327
Heifers	169	59
Total	1,732	1,199

Forage experiments

After weaning at approximately 5 to 7 mo of age, calves were placed onto grazing experiments. Experiments were classified by forage type and season, which were outlined by Gaertner et al. (1992). Cool-season forages (September 1 to March 15) consisted primarily of rye and ryegrass forage. Warm-season studies (March 16 to August 31) were conducted primarily on varieties of bermudagrass, including Coastal, Tifton 85, and common. In addition, arrowleaf and crimson clover (*Trifolium incarnatum*) were grazed with bermudagrass during some experiments. Performance data collected on cattle at the conclusion of grazing periods included BW, ADG, and BCS. In some instances, cattle were used in multiple experiments. After completion of one stocking experiment, cattle were then placed on another forage during the subsequent grazing season.

Various stocking rates were used and were classified as low, medium, and high. The variable stocking rate method used in the experiments was outlined by Gaertner et al. (1992). Low stocked pastures maintained greater than 2,400 kg/ha of forage, medium between 1,600 and 2,000 kg/ha, and high stocking rate pastures had less than 800 kg/ha of forage available.

Some cattle were given additional supplementation as part of specific supplementation experiments while on their designated grazing study. Depending on experiment, amount and ingredient of supplement varied. Supplement ingredients included fishmeal, cottonseed meal, soybean meal, feather meal, and corn gluten meal. In addition, corn, Rumensin and molasses were used for supplementation. For the purposes of this analysis, type and amount of supplementation were not uniquely separated. All animals that received any supplementation were classified as supplemented, while those that grazed pasture only were classified as not supplemented, and as such this was modeled as a 2-level fixed effect.

Statistical analysis

Data were analyzed using an animal model with ASReml (Gilmour et al., 2009). Comparisons of means for ADG, BCS at the end of the grazing period, and end of period BW were made for fixed effects that were included in the model. Unadjusted means, standard deviations, and minimum and maximum values for analyzed traits, as well as age of cattle are presented in Tables 5 and 6 by season. Heritabilities were estimated for each of the traits in each distinct stocking season.

Table 5. Simple statistics for cool-season forage performance traits

Trait	No. of records	Mean	SD	Minimum	Maximum
Body weight, kg	1,732	374.79	83.41	126.13	606.17
Average daily gain, kg/d	1,531	1.03	0.39	– 0.92	2.32
Body condition score	1,399	5.75	0.87	3.00	9.00
Age, d	1,732	433.30	54.56	189.00	616.00

Table 6. Simple statistics for warm-season forage performance traits

Trait	No. of records	Mean	SD	Minimum	Maximum
Body weight, kg	1,199	357.67	65.61	185.57	577.13
Average daily gain, kg/d	1,130	0.55	0.31	– 0.40	2.58
Body condition score	1,153	5.33	0.76	3.00	8.00
Age, d	1,199	405.02	73.20	252.00	676.00

CHAPTER IV

RESULTS AND DISCUSSION

Main effects included in the model included stocking rate (3 levels as previously described), supplementation (2 levels, i.e., supplemented or not supplemented), proportion Brahman (3 levels as previously described), and contemporary groups based on sex and year. Records from any contemporary group with less than 5 animals were removed from the analysis. Records from contemporary groups with average end of period age less than 200 d or greater than 540 d were removed from the analysis. Cool-season forage experiments included 43 contemporary groups, ranging from 7 to 104 animals, with an average of 40.3 animals per group. Warm-season forage experiments included 43 contemporary groups, ranging from 6 to 73 animals with an average of 27.9 animals. Interactions between fixed effects were analyzed and included in the model where applicable. Age in days at the end of the period was fit as a linear covariate. Across all models, additive genetic effects were included as random effects. Maternal genetic effects were investigated, but were omitted because they were always estimated to be 0.

Cool-season forage experiments

Body weight. For cool-season forages, contemporary group was a highly significant effect. All stocking rate means differed ($P < 0.001$; Table 7). All breed type means differed ($P < 0.001$; Table 8). The heaviest breed type was ¼ Brahman, followed by ½ Brahman calves and purebred Brahman, respectively. A large portion of the ¼ Brahman cattle were sired by Simmental bulls which gave them a greater genetic potential for growth than other calves in the study. The crossbred calves were heavier than the purebred calves, likely due to both breed differences and the effects of hybrid vigor. Supplemented calves had a greater BW than those that were not supplemented ($P < 0.001$; Table 9). For cool-season BW, linear regression coefficients on age in days (i.e., regression of weight at the end of the period on age at the end of the period) of calves with ¼ Brahman, ½ Brahman, and purebreds were 0.83 ± 0.042, 0.94 ± 0.120, and 0.58 ± 0.035 kg, respectively ($P < 0.05$). Regression coefficients for crossbred cattle were numerically greater than for purebred Brahman. However, the estimated coefficient for ½ Brahman was numerically greater than ¼ Brahman, even though the mean was greater for ¼ Brahman.

Table 7. Means and SE of performance traits at various stocking rates on cool-season and warm-season forages

		Stocking Rate	
	Low	Medium	High
Trait	Mean ± SE	Mean ± SE	Mean ± SE
Cool-season Forage			
BW, kg	393.81 ± 3.602 [a]	362.51 ± 3.108[b]	329.31 ± 3.687[c]
ADG, kg/d	1.26 ± 0.036[a]	1.02 ± 0.034[b]	0.77 ± 0.036[c]
BCS	6.62 ± 0.094[a]	6.18 ± 0.092[b]	5.55 ± 0.097[c]
Warm-season Forage			
BW, kg	355.17 ± 5.824[a]	337.33 ± 4.692[b]	322.67 ± 5.480[c]
ADG, kg/d	0.93 ± 0.038[a]	0.71 ± 0.030[b]	0.62 ± 0.035[c]
BCS	5.56 ± 0.103[a]	5.40 ± 0.080[a]	5.07 ± 0.094[b]

[a,b,c] Within traits (rows), means that do not share a superscript differ ($P < 0.01$).

Table 8. Means and SE of performance traits at various proportion Brahman on cool-season (cool) or warm-season (warm) forages

	Brahman proportion		
	¼	½	Purebred
Trait	Mean ± SE	Mean ± SE	Mean ± SE
BW (cool), kg	393.73 ± 2.996[a]	372.18 ± 4.757[b]	319.73 ± 4.686[c]
BW (warm),kg	386.74 ± 3.365[a]	319.87 ± 12.288[b]	308.57 ± 4.343[b]
ADG (warm), kg/d	0.62 ± 0.022[a]	0.98 ± 0.074[b]	0.68 ± 0.029[a]
BCS (warm)	5.38 ± 0.057	5.37 ± 0.194	5.28 ± 0.079

[a,b,c] Within traits (rows), means that do not share a superscript differ ($P < 0.01$).

Table 9. Means and SE of performance traits at various levels of supplementation on cool-season (cool) or warm-season (warm) forages

	Supplementation	
	Yes	No
Trait	Mean ± SE	Mean ± SE
BW (cool), kg	373.77 ± 4.738	349.98 ± 2.549
BW (warm),kg	347.80 ± 4.828	328.99 ± 4.588
ADG (warm), kg/d	0.86 ± 0.030	0.65 ± 0.029
BCS (warm)	5.49 ± 0.080	5.19 ± 0.076

For all traits, levels of supplementation differed ($P < 0.001$).

Average daily gain. Contemporary group was included in the final model for analysis of cool-season forage ADG ($P < 0.001$). All stocking rate means differed ($P < 0.001$; Table 7). Calves grazing at low stocking rates had the greatest ADG, followed by the medium and high stocking rates, respectively. Greater forage availability per animal at low stocking rates allowed for greater intake; thus, resulting in cattle with greater ADG than cattle grazing more heavily stocked pastures. The interaction between proportion Brahman and supplementation was included in the final model ($P = 0.002$; Table 10). Among the supplemented cattle, ¼ Brahman had the greatest ADG, while purebreds had the lowest ADG ($P < 0.03$). Among non-supplemented calves, ¼ Brahman calves did not differ from ½ Brahman calves ($P = 0.51$). The ADG of non-supplemented crossbred stockers was greater than for the non-supplemented purebreds ($P < 0.001$). Similar to BW, increased ADG in the crossbred calves was likely due to the effects of hybrid vigor and increased genetic potential for growth traits due to sire breed. For cool-season forage ADG, linear regression coefficients (i.e., the regression of the ADG for the period on age at the end of the period) on age in days were – 0.0002 ± 0.0004, 0.0031 ± 0.0008, and – 0.0008 ± 0.0004 kg/d for ¼ Brahman, ½ Brahman, and purebreds, respectively. Regression coefficients did not differ from zero for ¼ Brahman and purebreds.

Table 10. Means and SE of ADG on cool-season forage for all breed types and supplementation

Breed type	Supplemented Mean ± SE	Not Supplemented Mean ± SE
Purebred Brahman	$0.77 \pm 0.051^{a,x}$	$0.73 \pm 0.030^{a,x}$
½ Brahman	$1.18 \pm 0.178^{a,y}$	$1.06 \pm 0.29^{a,y}$
¼ Brahman	$1.30 \pm 0.036^{a,z}$	$1.04 \pm 0.016^{b,y}$

^{a,b} Within levels of breed type (rows), means that do not share a superscript differ ($P < 0.01$).
^{x,y,z} Within supplementation levels (columns), means that do not share a superscript differ ($P < 0.03$).

Body condition score. Contemporary group was highly significant. Body condition scores at the end of grazing period for cattle on low stocking rates were greater than those on medium stocking rates which were greater than cattle on high stocking rates ($P < 0.001$; Table 7). Increased forage intake of stockers on low stocking rate pastures allowed for greater deposits of fat than calves consuming less forage on higher stocked pastures. An interaction between Brahman proportion and supplementation was detected ($P = 0.02$; Table 11). Supplemented ½ Brahman calves had the highest BCS, while Brahman calves had the lowest BCS ($P < 0.01$). Body condition score means for non-supplemented ½ Brahman and Brahman did not differ ($P = 0.41$); however, non-supplemented Brahman and ¼ Brahman differed ($P < 0.04$). Means for BCS did not differ between non-supplemented crossbred calves ($P = 0.39$). Supplemented cattle had greater BCS than non-supplemented calves of the same breed type ($P < 0.02$). Since crossbred calves had a larger proportion of *Bos taurus* breed type, these cattle may have been more capable of maintaining body condition during the cool-season than purebred Brahman calves. All breed types had increased BCS associated with increase in age (i.e., age at the end of the period) in days (0.0044 ± 0.0007, 0.0066 ± 0.0025, and 0.0036 ± 0.0006 for ¼ Brahman, ½ Brahman, and Brahman, respectively; $P < 0.05$). Crossbred calves had a numerically greater regression coefficient than the purebred Brahman; thus, they may deposit fat more quickly.

Table 11. Means and SE of BCS on cool-season forage for all breed types and supplementation

Breed type	Supplemented Mean ± SE	Not Supplemented Mean ± SE
Purebred Brahman	$5.94 \pm 0.161^{a,x}$	$5.57 \pm 0.073^{b,x}$
½ Brahman	$7.36 \pm 0.473^{a,y}$	$5.67 \pm 0.087^{b,x}$
¼ Brahman	$6.42 \pm 0.095^{a,z}$	$5.74 \pm 0.044^{b,y}$

^{a,b} Within levels of breed type (rows), means that do not share a superscript differ ($P < 0.02$).
^{x,y,z} Within supplementation levels (columns), means that do not share a superscript differ ($P < 0.04$).

Warm-season forage experiments

Body weight. For analysis of BW at the end of warm-season forage experiments, contemporary group was highly significant. Means for BW on warm-season forages at all levels of stocking rate were displayed in Table 7. All BW means differed by stocking rate ($P < 0.01$). Calves grazing at low stocking rates had the heaviest weights, while calves grazing at high stocking rates had the lightest weights. Stockers with ¼ Brahman lineage had the heaviest weights, followed by ½ Brahman calves and purebreds, respectively, and all differed ($P < 0.01$; Table 8). The differences in BW between breed types during cool-season forage experiments differed from the differences between breed types during warm-season forage experiments. This was evidence of a potential genotype-environment interaction. The differences in BW between ¼ Brahmans and ½ Brahmans, ½ Brahmans and purebreds, and ¼ Brahmans and purebreds on cool-season forages were 21.55kg, 52.37kg, and 74 kg, respectively. Differences in BW between ¼ Brahmans and ½ Brahmans, ½ Brahmans and purebreds, and ¼ Brahmans and purebreds on warm-season forages were 66.87kg, 11.30kg, and 78.17 kg, respectively. The differences in BW differences between ¼ Brahman and ½ Brahman and ½ Brahman and purebreds changed with forage. While all breed types had lower BW on warm-season forages (not statistically tested), the difference between BW on cool and warm-season forages was smaller for purebred Brahman than ½ Brahman. Purebred Brahmans were potentially better adapted to the harsher warm-season environment, and consequently they may have performed more closely to their genetic potential than the ½ Brahman calves. Supplemented calves had heavier BW than non-supplemented calves ($P < 0.001$;

Table 9). The linear regression coefficients on age in days at the end of the grazing period for ¼ Brahman, ½ Brahman, and purebreds were 0.78 ± 0.066, – 0.20 ± 0.356, and 0.64 ± 0.027 kg, respectively. For ¼ Brahman and purebred calves, BW increased with an increase in age at the end of the experiment.

Average daily gain. Contemporary group was included in the model ($P < 0.001$). Stockers grazing pastures at a low stocking rate had greater ADG than calves grazing medium stocking rate pastures, and which had greater ADG than calves grazing high stocking rate pastures ($P < 0.02$; Table 7). Average daily gain for ¼ Brahman did not differ from purebred Brahmans, ($P = 0.10$), but ADG of ½ Brahman was greater than both ¼ Brahman and purebreds ($P < 0.001$). The ADG rankings of breed types for warm-season forage differs from the cool-season forage, wherein all breed types differed and ¼ Brahman had the greatest ADG. Average daily gain of supplemented calves was greater than ADG of non-supplemented calves ($P < 0.001$). Supplemented cattle were provided with more nutrients than non-supplemented cattle, which allowed them to meet their maintenance requirements and allocate a greater amount of nutrients to growth. Unique covariates of age at the end of grazing period for each level of proportion Brahman were not detected for ADG ($P = 0.15$).

Body condition score. Contemporary group was included ($P < 0.001$) for warm-season BCS. Body condition score did not differ ($P = 0.14$) between low and medium levels of stocking rate (Table 7); however, BCS at low and medium stocking rates differed from BCS at high stocking rates ($P < 0.001$). No BCS differences were detected for breed type ($P > 0.29$). Table 9 displays means of BCS for levels of supplementation.

Supplemented calves had greater (*P* < 0.001) BCS than stockers that did not receive supplementation (Table 8). The BCS from warm-season forage means were lower than cool-season forages (not statistically tested). Linear regression coefficients for BCS at the end of the period on age in days at the end of the period were 0.0035 ± 0.0012, 0.0049 ± 0.0063, and 0.0039 ± 0.0005 for ¼ Brahman, ½ Brahman, and purebreds, respectively. As final age in days increased, end of period BCS increased for ¼ Brahmans and purebreds.

Heritability estimates

Table 12 displays the estimated additive genetic variance for each trait measured on cool-season forages, as well as heritability and SE estimates. The estimate of heritability for BW on cool-season forages was mostly higher than previously reported estimates in similar cattle (Riley et al., 2002; Smith et al., 2007; Lima et al., 2013). However, Barwick (2009a) reported an estimate almost as large as that from the present study by analyzing live weight at the end of dry season in tropical composite heifers (0.74 ± 0.13). The estimate of heritability for ADG was similar to reports by Barwick et al. (2009a), Toral et al. (2011), and Caetano et al. (2013), which ranged from 0.16 to 0.30. The estimate of heritability for end of period BCS was in agreement with estimates previously reported by Arango et al. (2002) of beef cows in production, ranging from 0.18 to 0.25 for 2- to 7-yr-old cows. Heritability estimates indicated that ADG and BCS were more greatly affected by environment than BW. Lower heritability estimates for ADG and BCS suggested that change in these traits can be made through selection. However, change in these traits would be more difficult to achieve than in those with higher heritability such as BW.

Table 12. Additive genetic variance (trait units squared) and estimates of heritability (cool-season forages)

Trait	Additive variance	Heritability	SE
Body weight, kg	1346.340	0.72	0.094
Average daily gain, kg/d	0.008	0.14	0.083
Body condition score	0.103	0.25	0.099

The estimate of heritability for BW (Table 13) was similar to previously reported results of 0.47 and 0.59 of Riley et al. (2002) and Smith et al. (2007), respectively. The estimate of ADG heritability was similar to reports by Barwick et al. (2009b), Toral et al. (2011), and Caetano et al. (2013), which ranged from 0.16 to 0.30. Body condition score heritability estimate was within the range of 0.18 to 0.25 reported in Arango et al. (2002)

Table 13. Additive genetic variance (trait units squared) and estimates of heritability (warm-season forages)

Trait	Additive Variance	Heritability	SE
Body weight, kg	537.198	0.44	0.130
Average daily gain, kg/d	0.008	0.15	0.099
Body condition score	0.108	0.29	0.106

CHAPTER V

SUMMARY

Estimates of heritability from this study were the first using *Bos indicus*-influenced growing cattle estimates and analyzed distinctly by pasture season in the United States. In that regard, analyses were similar to the Barwick heifer experiments conducted during Australian wet and dry season (2009a). The estimate for live weight was greater during the dry season, and the heritability estimate for BW in these analyses was greater during cool-season grazing. Both experiments resulted in higher heritability estimates during the same type of weather pattern, as the Australian dry season corresponds to the cool-season defined in these analyses. Heritability for ADG was also greater during the dry season (Barwick et al., 2009a); whereas, estimates for ADG were similar for cool and warm-season analyses of this study.

The heritability estimate for BW on cool-season forage appeared to be unreasonably high when compared to other estimates of BW heritability, and in particular the BW for warm-season forage estimate. Some component of the phenotypic variance may have been wrongly attributed to additive genetic variance due to the structure of the model. There are several possible explanations for the discrepancy. Differences in breed type may affect estimates. In the Barwick et al. (2009a) analysis, tropical composite estimates for live weight heritability were significantly higher than for purebred Brahman. In the cool-season forage analysis of the present study, crossbred cattle accounted for over 75 percent of the cattle, compared to 66 percent of the warm-season forage analysis. The larger portion of crossbred cattle could result in a higher estimate for heritability. With an adequate sample size of all breed types, additional analyses of traits for each breed type in a season would be noteworthy, in order to compare results of the heritability estimate for ¼ and ½ Brahman to purebred Brahman traits for cool and warm-season forages. Differences between traits on different forages and seasons in *Bos indicus* type cattle were another potential factor for the high estimate. Brahman adaptation to warmer temperatures and lack of tolerance for cool weather suggested that BW in different seasons should not be interpreted as the same trait. In the analysis of the Barwick steers (2009b), as well as estimates reported by Koch et al. (1982), heritability estimates of weight and gain differed at various stages of production from weaning to the end of the feedlot period. While measurements at all stages were quantifying the same trait, the varying estimates suggested that environmental effects have greater influence in the stages directly after weaning compared to during feedlot periods, as heritability estimates increased later in these experiments. Measuring the same trait in different seasons could potentially have a similar effect.

While performance traits in stocker cattle are not normally selected for in a breeding program, traits such as BW of stockers are associated with measures such as weaning weight that are more often selected for. The differences in performance seen in breed types, grazing seasons, stocking rates, and supplementation strategies further demonstrated the effects of management on performance of stocker cattle. Using information gathered from the analyses, decisions can be made in regards to implementing management practices in a stocker operation. Utilizing lower stocking rates or supplementing calves can lead to increased performance, but it is crucial to analyze the costs associated with the new practices compared to the value generated.

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