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Cost Benefit Analysis of Genetic Markers in Cattle

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Table of Contents

List of Tables and Figures

Abstract

Genetic sequencing in beef cattle (L. *Bos Taurus*) is expected to aid producers select cattle with traits that enhance profitability. Using data from experimental trials conducted with Angus, Brahman, and their reciprocal cross, this project analyzes the profitability of grazing endophyte infected tall Fescue (L. *Festuca arundinacea Schreb.*) vs. Bermuda grass (L. *Cynodon dactylon)* pasture. The study is unique in the sense that actual cow-calf breeding failure rates (open cows were not culled) were tracked from 1991 to 1997 on herds that were bred to calf in spring and either exposed to fungal endophyte (L.*Acremonium coenophialum Morgan-Jones and Gams*) infected tall Fescue grazing and hay or not. Along with data on birth and weaning weights, the number of calves weaned over a cow's useful life were used as major determinants of economic performance using the Forage and Cattle Analysis Planning (FORCAP) decision support software. Using this economic performance measure in conjunction with gene sequencing information allows the selection of beef cattle with profit-maximizing traits (low breeding failure rate) to provide producers with information on which replacement heifers and cows to retain in their breeding stock and herd sires to select. The study examined the single nucleotide polymorphisms (SNPs) p450 C994G, to assess the genetic marker's power to improve the economic performance of the herd. Results suggest that for reciprocal cross herds primarily grazing Bermuda grass pastures the CC expression of the gene is most favorable whereas the GG and GC gene sequences were more profitable with tall Fescue. Adding genetic market information when selecting a production strategy led to approximately $15/hd in added profitability. At a prorated cost of $2.40/hd over the life of a dam it is therefore worth pursuing genetic information under the conditions observed in this study.

Introduction

Beef cattle farming has changed drastically over time. It used to be a source of food and power for pulling equipment for a family, but today, more people use cattle farming as a supplemental income source for their family. Larger herd sizes, changing household economics and a better understanding of performance implications of breed selection in light of environmental conditions faced in the field, led to this change. Further, ranchers cross cattle of different breeds to exploit hybrid vigor and improve herd performance by choosing herd sires and replacement heifers with desirable production traits such as low birth weight for calving ease and high weaning weight for greater revenue potential at time of weaning. Genetic selection for lowering breeding failure rate, a stronger indicator of cow herd economics, however, is more difficult and hence scientific advancements capturing an animal's genetic sequence at sufficiently low cost now may allow for decision making using this information.

The objective of this project is to assess whether cow-calf operations would benefit from genetic marker information as they contemplate production practices that would compare the relative profitability of: i) Endophyte infected tall Fescue (E^{+}) vs. Bermuda grass (*BG*) pasture management strategies on their operations to assess the impact of presence or absence of fescue toxicosis; ii) the interaction of pasture management with breed selection of purebred Angus, purebred Brahman or their reciprocal cross to demonstrate superior breed selection given available pasture resources; and iii) the interaction of pasture management × breed × genetic marker information to determine whether gene sequencing information can help enhance profitability of a cow herd over and above a strategy optimized based on only pasture management and breed information.

Literature Review

Dr. Rosenkrans and other animal scientists have broken down genomes of the bovine by documenting various genetic sequences or genetic markers that make up different phenotypes of cattle often summarized by their expected progeny difference (EPD) that distinguish cattle of a certain breed to a relative moving annual baseline standard either within or across breeds in terms of birth weight, weaning weight, yearling weight, milk, marbling, ribeye area, fat thickness and carcass weight (Kuehn and Thallman, 2016a,b). Hence, farmers examining within- and across-breed based expected progeny differences (EPDs) for making choices involving the genetic makeup of their herd can choose genetics to improve herd performance (Keeton et al., 2014). However, genetic marker information provides a more precise method of developing consistent herd and feedlot performance (Brown et al., 2010; Looper et al., 2010; Rosenkrans et al., 2010; Sales et al., 2011a,b; Thompson et al., 2014).

Looper et al. (2010), conducted a study over the Prolactin (PLR) gene region. This study examined Angus, Brahman, and their reciprocal cross on tall Fescue and Bermuda grasses. They observed the PRL enhancer gene region of the cow to determine if a genetic marker had a noticeable effect on calving rate, birth weight and hip height. The results of the blood test revealed that at two different SNP sites calving rate did not differ (Looper, et al., 2010). This suggests that PLR does aid in mammal reproduction just not as a potential genetic marker. Although, calving ease and birth weights are important for profitability, calving ease and birth weights are not the only traits that can determine profitability in cattle. The study concluded that more research on a larger herd is necessary to determine profitability.

A study conducted by Thompson et al. (2014) observed the value of genetic information for the management and selection of feedlot cattle. The research goal was to determine if cattle possessing differences in their genomes would mature in different ways through the feeding process. This study looked at 7 traits of feedlot cattle, to determine the expected genetic value of livestock during the feedlot stage (Thompson, et al., 2014). The data obtained was then utilized to estimate differences in average daily gain. Results showed that the benefit cost ratio for selection using certain traits was very low. However, the study did reveal that genetic potential revealed in genetic traits could lead to higher profitability. They found positive changes in profitability of $22 per head for a single trait and as much as $38 per head for multiple-traits (Thompson, et al., 2014). This suggests that not only birth weight (BW) but also 205 d weaning weight (WW205) and feedlot performance are important for genetic selection and attendant economic performance.

Sales et al. (2011b) focused on the genetic sequence labeled as p450 C994G among others. This marker is expected to be helpful for determining resistance to toxic fescue. Pastures of E^+ cause a host of detrimental bovine responses. Among them are breeding failures and relatively poor weight gain in offspring as recently analyzed by Caldwell et al. (2013) and Smith et al. (2012). While animal performance is negatively affected by E^+, pastures of this forage are also more drought tolerant than other cool season forages and many pastures in the mid-Southern U.S. have a significant portion of grazable forage made up of E^+ that is able to persist in pastures despite significant heat stress during the summer months. To combat fescue toxicosis, producers can seed their pastures to *BG*, free of toxin and heat tolerant, at the cost of added hay feeding during the fall, winter and spring months when cool season fescue would normally offer grazing opportunities for pasture-fed beef cattle (Figure 1). As shown in Figure 1, fescue offers grazing potential primarily in the spring and fall but also part of the summer such that cattle are estimated to graze pasture for 269 d with 96 d on hay using a cow-calf simulation model (Forage and Cattle Analysis and Planning – FORCAP) under conditions that mirrored the E^+ treatment in

Brown et al.'s (1997) study of E^+ and *BG* pastures. At the same time, grazing of hay land during October and November still allowed 98 bales of excess hay sales given a description of farm conditions detailed below. Cows solely on *BG* pasture and hay, however, face a different growing season concentrated to summer months and as such graze only 178 d on pasture while being supplemented with hay for 187 d as shown in Figure 1 under the BG treatment conditions using FORCAP where now only 35 excess hay bales could be sold and hayland grazing was not an option as no forage growth occurred during October and November. Hence, using *BG* leads to more hay feeding but does not expose cattle to deleterious effects of E^+. Another option for managing E^+, however, is to modify the genetic makeup of the herd to be more tolerant of these toxins.

Materials and Methods

As described in Brown et al. (1997), purebred Angus, purebred Brahman and their reciprocal cross dams were bred to Hereford sires with calves born in spring of 1991 to 1997 at the Booneville, AR USDA ARS Dale Bumpers Small Farms Research Center (N 35° 5' 42", W 93° 57' 50"). Animals were placed on either E^+ pastures or *BG* pastures and fed hay of similar type by treatment to ensure a fixed treatment effect of fescue toxicosis that could be observed by breed of dam. To eliminate sire effects, herd sires were rotated across pastures in 13 d intervals throughout the 75 d breeding period. Since some cows had to be replaced in cases where caesarian-sections or uterine prolapse could affect reproductive performance given human interaction or because cows died over the experimental period, not all cows were exposed the same number of times to calculate observed breeding failure rates over the 7 yr study period (Table 1). In addition to observed breeding failure rates defined as:

(1) *BFR* = 1 - # of calves born / # of times the cow was bred

birth weight, sex of calf and 205 d weaning weight data, and genetic marker information on the dam were available along with calving date to capture information needed to perform economic analysis. Cows were fed supplement to ensure adequate body condition score in a similar manner across all treatments.

Using *BFR* along with birth weight, weaning weight, and calving month, the decision support tool for cow-calf operations, FORCAP, was used to capture treatment effects on model farms that primarily differed by pasture system employed as already discussed above (Popp et al., 2013). FORCAP was developed to aid farmers and researchers with analyzing the impacts of:

- input cost and output prices for cattle, fertilizer, feed, marketing charges, fuel, winter annuals, fencing, property tax, insurance, ownership charges of equipment, building and breeding herd investment, operating interest, and major veterinary charges;
- breakdown of land resources for pasture and hay along with amount, type and frequency of fertilizer applications and forage species selection;
- pasture management strategies involving fencing and watering cost, expected grazing efficiency, type and amount of winter annuals, stockpiling and strip grazing preferences;
- cattle production parameters including annual breeding failures, expected cow and calf losses, specification of typical cow replacement age, average mature and young cow weights, weaning age and weights, birth weights and age of first breeding as well as calving season, stocking rate and expected hay waste;
- feeding of extra cattle either retained from own production or purchased using a host supplement feed options;
- managing excess forage using haying equipment, if feasible, in rotationally grazed pastures or fall grazing of hay land when pasture resources are limited.
- hauling and transport decisions
- vaccination program and expected frequency of veterinary services; and
- capital requirements associated with breeding stock, equipment, and buildings along with repair and maintenance, property tax and insurance cost estimates.

In FORCAP, under the ‘Cattle’ tab, a particular cow’s average birth weight for calves as well as their average steer and heifer 205 d weaning weights, *BFR* and average calving month were entered as shown in Figure 2 with the remainder of cow-calf operating parameters held constant except for forage species (Figure 1) utilized. These operating parameters are summarized in Tables 2 to 4 and mirror experimental conditions employed in the original study except that poultry litter was used instead of commercial fertilizer and supplement was not fed as, according to FORCAP, minimal additional nutrition aside from hay was needed to maintain adequate body condition score. As such, net cash return estimates per cow exposed to a herd sire are the revenue from the sale of cattle and excess hay less cash expenses for feed, fertilizer, veterinary and medicine, fuel, twine, repair and maintenance, and operating interest. These net cash returns form the FORCAP estimate of the profitability of a particular animal. Further, it is assumed that the performance of a cow could be replicated or would be similar for a cow with the same genetic marker, breed and pasture management and as such, the profitability estimate of a cow could be extrapolated to herd performance (83 cows in this case to capture a continuously grazed cattle operation for this production region deemed of adequate size to consider obtaining genetic marker information). A ten-year average was used for prices of cattle and fertilizer to remove potential distortion of profitability due to cyclically high or low prices. Seasonality in prices was captured by modifying the calving month and using weaning weight dependent sales prices for the attendant sale month (AMS, 2017). Ten-year average monthly prices for cattle of different weight (Table 2) were also deflated using U.S. All Beef Cattle prices for animals marketed at weights greater than 500 lbs to convert beef prices to constant 2016 dollars (NASS, 2017a). For fertilizer, a fertilizer price index was used to deflate to 2016 dollars (NASS, 2017b).

Finally cost of production estimates for fuel, twine and other inputs were obtained from local sources and reflect cost conditions faced by beef producers in 2016.

Estimates of cow profitability were then regressed against explanatory factors involving genetic marker information, breed, forage species selection, *BFR*, birth and weaning weight variables and select interactions to assess their relative economic impact as follows:

$$(2)\qquad NR = a_0 + a_1 \cdot E^+ + a_2 \cdot ANGUS + a_3 \cdot BRAHMAN + a_4 \cdot BFR + a_5 \cdot BW + a_6 \cdot WW205$$
$$+ a_7 \cdot GC + a_8 \cdot GG + a_9 \cdot E^+ \times ANGUS + a_{10} \cdot BFR \times E^+ + a_{11} \cdot BFR \times ANGUS$$
$$+ a_{12} \cdot BFR \times BRAHMAN + a_{13} \cdot BFR \times GC + a_{14} \cdot BFR \times GG$$

where E^+ is a binary 0/1 variable indicating presence (1) or absence (0) of fescue toxicosis as implied by either using E^+ as the primary pasture and hay forage species or alternatively using *BG* for pasture and hay signaling the absence of fescue toxicosis, *ANGUS* or *BRAHMAN* are binary variables indicating breed, *GC* and *GG* are binary variables indicating presence or absence of p450 G994C (GC) or p450G994G (GG) marker expressions, *BW* is the average birthweight of steers and heifers born to a particular cow and *WW205* is the 205 d adjusted weaning weight equally weighted between steers and heifers as observed in the experiment. The base line represents a reciprocal cross of Angus × Brahman with a CC marker expression on *BG* pasture and hay devoid of fescue toxicosis pressure as those observations were most frequent in the data set. *BW* and *WW205* are included as explanatory variables as bull EPD statistics typically include values for these parameters. The error term for Eq. 2 is purposely omitted since estimates of *NR* were obtained deterministically in FORCAP. Finally, alternative specifications of the Eq. 2 were estimated with the final specification chosen to i) capture mainly *BFR* interactions with pasture, breed and marker, but ii) also on the basis of goodness of fit using adjusted R^2 and by evaluating the addition or removal of explanatory interactions of variables, that warranted inclusion given expert opinion, on the basis of the absolute value of their t-statistic (| t –stat | > 1.0). The latter approach limits effects of multicollinearity on coefficient estimates for explanatory variables (Gujarati, 2007).

To answer the questions raised in the objectives above, *NR* could be calculated and compared across pasture system, breed, and genetic marker. As an example, for the *BG* pasture system with reciprocal cross cattle and the CC marker, or the baseline, using the estimated coefficients in Eq. 2 would lead to a profitability estimate for those type of cattle on *BG* pasture as follows:

(3) $NR_{BG,\ Cross,\ CC} = a_0 + a_4 \cdot \overline{BFR}_{BG,Cross,CC} + a_5 \cdot \overline{BW}_{BG,Cross,CC} + a_6 \cdot \overline{WW205}_{BG,Cross,CC}$

where the *a*'s are coefficient estimates from Eq. 2 and $\overline{BFR}$, $\overline{BW}$, and $\overline{WW205}$ are sub sample averages from observations pertaining to those observations collected on *BG* pastures for reciprocal cross cattle with the CC marker. Changing to E^+ pastures for cattle of the same breed and marker, the applicable additional coefficients, a_1 and a_{10} as shown in Eq. 2, were used with subsample averages for *BFR*, *BW* and *WW205* for cattle on E^+ in a similar fashion as shown in Eq. 3. This process was repeated for the 2 pastures × 3 breeds × 3 marker expressions for estimates of 18 *NR* for each treatment combination. To allow comparisons of *NR* across pasture and pasture × breed, the technical appendix highlights analysis of variance (ANOVA) results undertaken for those comparisons. Further, As the ANOVA did not use explanatory variables of *BFR*, *BW*, and *WW205*, the technical appendix provides the pasture × breed × marker comparisons for illustration purposes only.

Ultimately, the target was to analyze if the *NR* of the best marker based selection for a particular forage and breed exceeded the pasture based and/or the pasture × breed based selection by more than the cost of getting the marker information to then determine if the cow-calf operator would benefit from getting herd sires and his/her existing breeding stock sampled for the p450 C994G marker.

In order to have a cow tested for genetic markers you must either collect hair or draw blood from the animal. The producer would incur negligible cost to collect hair whereas a blood sample is estimated to cost $3/hd. Once blood or hair is collect there is an additional cost of $8/hd to have the blood or hair tested. Adding administrative overhead of $1/hd, a $12/hd cost would be a conservative estimate for obtaining genetic marker information. Having your herd tested thus represents more than a trivial cost. Note, however, that this test only needs to be performed once over the life of the cow. For the observed study conditions in Brown et al. (1997), the average number of breeding exposures per cow was five. Hence, an annual cost of testing per head would be $12/5 or $2.40/hd. Profitability gains with breeding stock selection based on breed × pasture × genetic markers compared to breed and breed × pasture selection thus needs to exceed $2.40/hd for cow-calf operations analyzed in this study.

Finally, to test for the impact of seasonality and the potential impact of modified levels in breeding stock investment, the net return estimates in Eq. 2 were also calculated ignoring seasonality by setting the calving month to 100% March in Figure 2 for all observations and by including fixed costs for a cow-calf operation by including taxes, insurance and capital recovery charges for the buildings and equipment as listed in Table 4 along with an opportunity cost of capital invested in breeding stock. Regression analyses on *NR* thus were conducted using Net Cash Returns including seasonality as determined by calving month (S+), net cash returns without seasonality (S-), and, finally, net returns above cash expenses and ownership charges (S+OC) . Should analyses of NR specified in these three different ways lead to the same conclusions, the results are deemed more robust.

Results

This study examined 86 cows. There were a total of 24 Angus cows, 28 Brahman cows, and 34 reciprocal crosses. Of all cows, 37 cows were on E^{+} pasture and hay whereas 49 cows grazed on *BG* pasture and were fed BG hay. The 86 observations were then broken down further into their genetic marker determined from the p450 C499G SNP. There are 3 different genetic marker expressions, CC, GC, GG. Each marker was represented on E^{+} (17 CC, 15 GC, 5 GG) and *BG* (25 CC, 18 GC, 6 GG) with difference across breed and pasture system detailed below.

Regression results breaking down the effects of breeding failure rate, birth weight, weaning weight, breed, marker, and pasture system (Eq. 2) are shown in Table 5. Coefficients were of the expected sign and adj. R^2 suggested that misspecification was not an issue. Further, coefficient estimates were statistically significant and justified estimation of profitability by pasture × breed × marker combination. Results are only shown for the regression statistics on cash net returns using seasonally adjusted prices. Including seasonality and ownership charges in profitability estimates had minimal impact on statistical significance and sign of coefficient estimates and were therefore not shown but are available from the authors upon request.

Table 6 demonstrates actual profitability differences by pasture and pasture × breed, as well as estimated profitability differences by pasture × breed × marker that vary whether seasonally adjusted sale prices were used (S+), sales were all based on October sales given a single March calving month (S-) or whether capital costs associated with retaining additional replacement heifers to account for higher culling rates with greater *BFR* were included along with seasonal sale price effects (S+OC). Note that the estimates of profitability were calculated using the appropriate coefficient estimates from Table 5 for Eq. 2 with appropriate subsample averages depending on production strategy employed as shown in the left-most column of Table

6. Using BG pasture with reciprocal cross cattle and CC marker information, for example, net cash returns per head were estimated as:

$$NR_{S+,BG,Cross,CC} = 120.48 - 810.87 \cdot 0.04 + 1.08 \cdot 79.1 - 0.06 \cdot 562.5 = 139.72 \text{ or}$$

$$a_0 + a_4 \cdot \overline{BFR}_{BG,Cross,CC} + a_5 \cdot \overline{BW}_{BG,Cross,CC} + a_6 \cdot \overline{WW205}_{BG,Cross,CC}$$

and were reported at $141.91 in Table 6 using higher precision using subsample averages of explanatory variables. Note that the other coefficients are not used as the E^+, breed, and genetic marker variables were set to zero for this subsample and hence their coefficient estimates did not play a role.

Discussion

As shown in Table 6, when comparing E^+ to *BG* forage systems with the average weights and average *BFR, E^+* forage systems outperform the *BG* system (also shown in Appendix Figure 1A). Given the presence of fescue toxicosis this is puzzling. However, when examining Figure 1 this is understandable. The advantage of E^+ forage systems is the ample opportunity to graze throughout the year and therefore feeding less hay. If a producer were thus interested in managing fescue toxicosis using the *BG* system and paid no attention to breed or genetic markers, his or her choice would be to pursue an E^+ system as the cost of feeding hay for nearly half of the year is simply too high to offset the gain in weaning weight observed in this study even though the ANOVA equality of means test showed no statistically significant differences.

If the producer now adds breed selection to his repertoire of decision making, then the optimal solution is to have an E^+ forage system and the reciprocal cross of Angus × Brahman cattle (Appendix Figure 1B). A logical explanation for this is hybrid vigor. Angus tend to show better reproductive performance with fewer breeding failures while Brahman deliver heavier weaning weights with the reciprocal crosses excelling on both fronts regardless of pasture system employed (Table 6). Note that on *BG* systems weaning weights are higher with the elimination of fescue toxicosis. However, heavier calves exacerbate the problem of hay feeding as more forage consumption leads to even greater hay needs and higher weight calves also lead to lower price per cwt. A *BG* × *BRAHMAN* strategy in particular, showed negative cash returns not only because of hay feeding but also poor reproductive performance with high *BFR.* Adding breed information compared to only using pasture system information led to higher returns with reciprocal cross cattle on *E+* pastures having the highest observed S+ returns among choices based on breed and pasture systems at $169.64/hd.

Finally, considering the addition of p450 C994G SNP on E^{+} forage systems, the optimal solution is to have the GC marker in reciprocal crossed cattle resulting in an estimated $184.99/hd cash returns given the conditions enumerated above (Table 6). Negligible *BFR* in conjunction with highest weaning weight when compared to a similar system with the GC marker that had similar low *BFR* showed that lighter weaning weights lead to lower cattle revenue. Not having the most frequently observed CC marker enhanced reproductive performance leading to greater estimated returns. Similar to results shown above for the pasture × breed-based profit-maximizing choice, the *BG* system was inferior to the *E+* system as crossbred cattle with either the GG or GC marker had larger *BFR.* Higher weaning weights across all markers were not sufficient to offset costs associated with elevated *BFR* with *BG* compared to E^{+}. Noteworthy, and not taken into consideration here, however, is the future fate of calves in feedlots starting at lower weaning weight due to their exposure to *E+* pastures. Nonetheless, adding marker information would allow the producer to gain approximately $15 per head per year ($184.99/hd with E+, Cross, GC vs. $169.64/hd on E+, Cross) which is approximately six times the cost of getting the added information conservatively estimated at $2.40/hd above.

The CC marker performed best on *BG* pastures without fescue toxicosis stress. This suggested the p450 C994G marker indeed measures cattle's ability to deal with toxicosis stress and more so on the reproductive performance end (*BFR*) than in terms of weaning weight.

Removing seasonality effects led to the same conclusions as just discussed above. Profitability estimates were lower on average as seasonal sale prices in October are typically the lowest. Adding ownership charges of cattle to reflect added cost of carrying replacement heifers with higher *BFR* also led to similar conclusions. This suggests that while a sensitivity analysis on hay prices, that may also play a role, was not undertaken, that the results above are robust to the changes analyzed.

Conclusion

The research conducted set out to prove whether it would be profitable for a producer to have their cattle genetically tested to gain information about the p450 C994G marker sequence for tolerance to fescue toxicosis. For cow-calf operations using breeds of Angus and Brahman cattle and grazing on tall Fescue or Bermuda grass pastures, as is common for large regions in the U.S., the results suggested that the genetic marker analyzed indeed would allow producers to enhance their operation's profitability in comparison to a strategy selection purely based on pasture management and breed alone. The results are therefore similar to Thompson et al. (2014) findings and add to information already reported by Looper et al. (2010) and Sales et al. (2011 a,b).

A limitation of the study is that a mixed pasture system consisting of both *BG* and *E+* pastures was not among treatments. Further, had genetic marker information been collected on the calves, weaning weight differences could have been analyzed for genetic marker information. Finally, had calves been tracked through the feedlot stage, an overall economic performance for not only cow-calf operations would have been possible. It is possible that a *BG* pasture system or even a mixed *BG* and *E+* pasture system could lead to better industry performance as both would potentially mitigate fescue toxicosis effects not only at the cow-calf but also through the feedlot stage of the industry.

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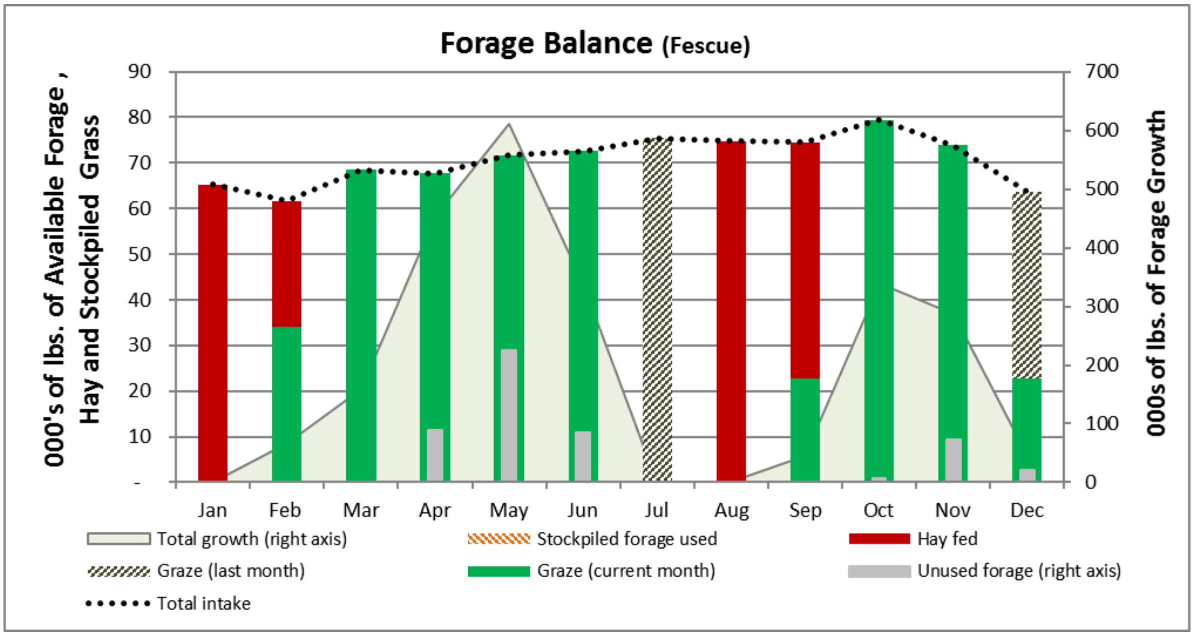
Figure 1. Sample Forage Balance for Fescue (E^+) vs. Bermudagrass (BG) Pasture Systems as modeled in FORCAP.



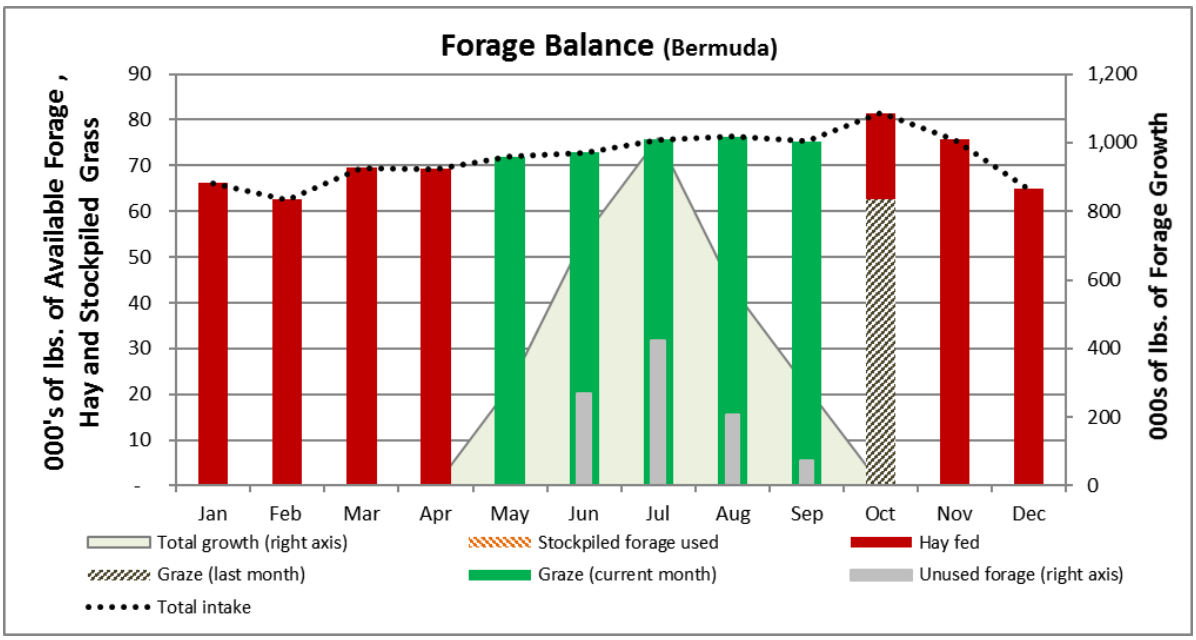


Figure 2. Sample Cattle Input Interface in FORCAP.

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Cattle Herd Make Up and Performance Statistics

FORCAP
FORAGE & CATTLE PLANNER

Press Reset for default values below Description	Reset Bench Mark	Press OK below for defaults based on 'Your Farm' options or enter your own below and to the right	Your Farm (includes impact of extra cattle)
Days on Hay & Supplements	169		96
Days on Pasture	196		269
1. Breeding failures	14%	OK	0%
Cow death losses	1.0%	OK	1.0%
Calf death losses	3.0%	OK	3.0%
Avg. culling age of cows	7.83		6.83
Avg. number of calves over life of cow	6	OK	5
Weight of mature cow in lbs	1,250	OK	1,200
Weight of young cow (at first calf) in lbs	1,000	OK	900
2. Weaning age in months	7	OK	7
Avg. age of replacements at first breeding	15	OK	15
Avg. birth weight in lbs	90	OK	90
Avg. steer weaning weight in lbs	555	OK	555
Avg. heifer weaning weight in lbs	520	OK	520
Avg. herd sire weight in lbs	2,000	OK	1,850

3. Calving Season			
... choose your calving season	Year round		Spring
OR provide more detail for your farm	Birth Month(s)	% of calves born	Sale Month(s)
... select up to four calving months together with likelihood in %. This is used to determine timing of herd feed intake and the average sale price for the calves sold at the weaning age specified above	Jan	0%	Aug
	Feb	25%	Sep
	Mar	50%	Oct
	Apr	25%	Nov
	Total	100%	

Herd Size and Description	Bench Mark	Press OK for Our Defaults Based on Your Farm Options or Enter your own to the right	Your Farm (includes impact of extra cattle)
Cows	50	... the ratio of cows to young cows depends on no. of calves over cow life	66
Young Cows	10		17
Cow herd size	60	OK	83 6.
Replacement	10	... check breeding failures and cow losses	17
Herd Sires	3	... based on 'Bull Estimator'	4
Calves Sold		... based on calf losses, 50/50 steer/heifer calf ratio, replacements retained, cow losses and average culling age as listed in the 'Bull Estimator'	
Male	25		40
Female (you buy replacements if negative)	15		23
Cull cows	9		16
No. of years between bull purchases	1.33		1.00
Death losses			
Cows	1		1
Calves	2		3
Hay Waste with feeding & storage	20%	OK	20%
Hay produced (from hay & pasture acres in bales)	371		355
Hay fed (in bales -- accounts for waste)	350		257
Number of 1200 lb. round bales sold (bought if negative)	21		98 5.
Pasture acres per cow	3.0	... bench mark changes with fertilizer option (Farm), modify on your farm by selecting a different cow herd size	4.8
Net Cash Returns ($)	15,768	GHG (lbs. CO_2 / lb sold)	22.59
4.	$189.98		

Note: Ignore the bench mark farm information and focus on the Your Farm information that is tailored to a particular cow deemed representative of the herd. Adjusted for each cow were, (1) breeding failure rate to estimate herd performance if all cows had a specific genetic market of the experimental cow, (2) birth and weaning weights observed after 7 months on pasture, (3) modal calving month for the cow to reflect potential for seasonal price fluctuation, (4) estimated farm level net cash returns defined as cattle and excess hay (5) revenue less cash expenses for feed, fertilizer, veterinary and medicine, fuel, twine, repair and maintenance, and operating interest and divided by number of cows (6) exposed to the herd sires.

Table 1. Frequencies of Observations by Number of Times Bred for Bermuda and Fescue Pasture Systems, Booneville, AR, 1991-1997.

Number of times bred[1]	**Bermuda**[2]	**Fescue**[2]
	# of observations	
7	6 [3]	6 [3]
6	12	6
5	6	7
4	12	4
3	5	6
2	6	6
1	2	2
Total number of cows per pasture system	49	37

Notes:
[1] Number of times a cow was bred over the period 1991-1997.
[2] Pasture systems on the basis of primary forage of Bermudagrass (BG) or endophyte-infected tall fescue (E^+).
[3] Number of cows per number of times bred. Frequency distributions were not statistically different (p=0.29) across pasture systems.

Table 2. Prices and costs used by FORCAP[1].

Item and Description	Unit	Price	Item and Description	Unit	Price
Livestock			**Feed**		
4 - 500 lb. steers[2]	$/cwt	170.62	Hay delivered/sold FOB -- 5' x 5' (1,200 lbs)	$/bale	60.00
5 - 600 lb. steers	$/cwt	153.48	Salt & minerals (50 lb bag)	$/bag	20.00
6 - 700 lb. steers	$/cwt	142.41	**Fertilizer**		
7 - 800 lb. steers	$/cwt	136.83	Lime	$/ton	33.10
3 - 400 lb. heifers	$/cwt	146.13	Ammonium nitrate (34-0-0)	$/ton	338.64
4 - 500 lb. heifers	$/cwt	135.48	Poultry litter (3-2-3)	$/ton	18.74
5 - 600 lb. heifers	$/cwt	129.15	Application cost per acre	$/acre	4.61
6 - 700 lb. heifers	$/cwt	125.76	**Fuel Use & Other Miscellaneous**		
Cull cow[3]	$/cwt	64.35	Amortized pasture/hay maintenance & establishment[5]	$/acre	14.00
Purchase price of breeding bull	$/hd	2,000			
Cull bull[4]	$/cwt	80.77	Fuel use for mowing, raking, and staging	gal/acre	4.50
Beef check off, ins. & yardage	$/hd	1.00	Fuel use per day for feeding	gal/70 cows/day	1.19
Sales commission (% of sales)	%	3.50	Fuel use per day for checking cattle	gal	1.00
Veterinary Services Charges			Fuel cost	$/gal	1.70
Prolapse	$/hd	75	Twine	$/bale	1.00
Caesarian section	$/hd	225	Cost for farm vehicle ($/hd/month)	$	1.00
Sick treatment (avg. drug charge)	$/hd	15	Capital recovery rate[6]	%	5.00
Bull soundness	$/hd	30	Operating interest[7]	%	4.75

Notes:

1 Forage and Cattle Planner.

2 State average, medium and large frame No. 1 prices as reported by the United States Department of Agriculture, Agricultural Market Service. A ten year average was used for sale months that were split across several marketing months with a specific calving distribution and depended on weaning age. Shown are the sale prices for cattle when selecting a spring calving season with 25% of calves born in February and April and 50% born in March. Prices were deflated using average US beef cattle prices. Further, calf prices are linearly interpolated across weight categories to adjust for specific sale weight.

3 75-80% Lean Breaking Utility.

4 Yield Grade 1-2, 1,000 to 2,100 lbs.

5 Based on 10-year life of stand and standard seedbed preparation and weed control expenses.

6 Capital recovery rate is used for estimating ownership charges on equipment and buildings and is also used for the opportunity cost of investment in breeding stock.

7 Charged on half the cash operating expenses incurred per year to reflect likely operating credit line expense.

Table 3. Sample[1] summary of cattle and hay management practices on Fescue.

Description		**Herd Size and Description**	
Days on hay & supplements[2]	96	Cows (avg. age 65 months)	66
Days on pasture[2]	269	Young cows (avg. age 30 months)	17
Breeding failures[3]	18%	Cow herd size[6]	83
Annual cow death losses	1%	Replacement heifers	17
Annual calf death losses	3%	Herd sires or bulls needed[7]	4
Avg. culling age of cows	6.83	Male calves sold	33
Avg. number of calves over life of cow[4]	5	Female calves sold	16
Weight of mature cow in lbs	1,200	Cull cows	16
Weight of young cow (at first calf) in lbs	900	No. of years between bull purchases	1.00
Weaning age in months[5]	7	Cow death losses	1
Avg. age at first breeding	15	Calf death losses	2
Avg. birth weight in lbs	80	Hay waste with feeding & storage	20%
Avg. steer weaning weight in lbs	492	**Hay (1,200 lb. round bales)[8]**	
Avg. heifer weaning weight in lbs	464	Hay produced	355
Avg. bull weight in lbs	1,850	Hay sold (purchased)	98
Calving season	User-selected[5]	Pasture acres per cow[5]	4.8

Notes:

1 Results are for a cow-calf operation with 125 acres of hay and 400 acres of pasture planted to endophyte-infected tall fescue (E^+). Fertilizer is added in the form of poultry litter (3-2-3) on hay and pasture at a rate of 2 tons per acre. Pastures are continuously grazed and cattle are allowed to graze hayland during October and November.

2 Will vary with calving month, breeding failure rate and calf weaning weight as grazing demand considers animal weight and herd size on a month to month basis.

3 Varies by cow and grazing system. Higher breeding failure rates are expected for E^+ pastures. Actual experimentally observed long term breeding failure rates are used by cow.

4 Determines the culling age for cows and hence the number of replacement cows needed in conjunction with breeding failures.

5 Calving season affects sale prices and seasonal nutrient needs of the herd.

6 Cow herd makeup is described for first-bred, young cows, and older cows in the rows above the cow herd size row. The cow herd size is the number of animals bred per year. Cow herd size also drives the stocking rate shown in pasture acres per cow.

7 The number of herd sires is determined by the total number of first-bred, young cows, and older cows in the herd. This analysis assumes that one bull can service a maximum of 25 cows. Bulls are assumed to be replaced every four years.

8 A negative number implies greater hay needs than available from farm production and hence hay purchases.

Table 4. Estimated capital requirements for an operations with 83 cows exposed to a herd sire on 400 acres of continuously grazed pasture with 125 hay acres as modeled in FORCAP[1].

Description	List Price	Years of Useful Life	Salvage Value	Capital Recovery	Repair Factor	Repair and Maintenance	Insurance & Property Taxes
Hay Barn (1,000 sq. ft.)	$5,000	20	$800	$377	0.40	$100	$65
Shed (800 sq. ft.)	$4,000	20	$750	$298	0.40	$80	$52
50-75 hp Tractor	$30,000	10	$10,000	$3,090	0.25	$750	$390
Disk Mower	$8,000	7	$4,000	$891	0.35	$400	$104
Hay Baler	$20,000	10	$7,500	$1,994	0.10	$200	$260
Hay Rake	$4,000	10	$750	$458	0.20	$80	$52
Stock Trailer	$3,500	10	$1,500	$334	0.20	$70	$46
Hay Wagon	$3,000	10	$500	$349	0.20	$60	$39
Brush Mower	$8,000	10	$800	$972	0.25	$200	$104
Corral and Chute	$3,500	10	$1,000	$374	0.15	$53	$46
Miscellaneous Items	$2,000	10	$0	$259	0.50	$100	$26
Fencing & Watering	$33,306	20	$0	$2,673	0.10	$167	-
Total Equipment & Buildings	$124,306			$12,069		$2,259	$1,183
Breeding Stock	Qty	Price	Value				
Cows	66	$850	$56,100	$2,805			
Young Cows[2]	17	$1,000	$17,000	$850			
Replacement Heifers[2]	17	$900	$15,300	$765			
Herd Sires	4	$2,000	$8,000	$400			
Total Breeding Stock	104		$96,400	$4,820			

Notes:

1 Forage and Cattle Planner.

2 The need for more or fewer replacement heifers given changes in breeding failure rates modifies breeding stock investment and thereby the opportunity cost of capital employed in the cattle operation. Opportunity cost represents returns foregone if money invested in cattle were invested elsewhere. As such, the annual opportunity cost of cattle is $96,400 times the 5% capital recovery rate.

Table 5. Multivariate Regression Statistics for Forage Production, Breed, and Marker Effects.

Variable		Coefficient (Std. Error)	T-Statistic
Constant	a_0	119.79 (43.14)***,1	2.78
$E^{+,2}$	a_1	3.39 (9.61)	0.35
ANGUS	a_2	-57.65 (13.00)***	-4.44
BRAHMAN	a_3	2.49 (11.37)	0.22
BFR	a_4	-808.88 (44.41)***	-18.21
BW	a_5	1.11 (0.43)**	2.58
WW205	a_6	-0.06 (0.08)	-0.80
GC	a_7	4.25 (8.46)	0.50
GG	a_8	-5.53 (12.03)	-0.46
$E^+ \times$ *ANGUS*	a_9	50.10 (13.77)***	-3.64
BFR $\times E^+$	a_{10}	-156.72 (29.40)**	5.33
BFR × *ANGUS*	a_{11}	144.77 (50.70)***	2.86
BFR × *BRAHMAN*	a_{12}	-53.04 (47.67)**	-1.11
BFR × *GC*	a_{13}	35.06 (32.05)	1.09
BFR × *GG*	a_{14}	105.98 (53.25)*	1.99
R^2		97.65%	
Adj. R^2		97.19%	
# of obs.		86	

Notes:

1 * < 0.1, ** <0.05, and *** <0.001 level of significance.

2 E^+ is a binary (0/1) variable and represents the presence of endophyte infected tall fescue as feed source on pasture and from hay. *ANGUS*, *BRAHMAN*, *GC*, and *GG* are also binary variables indicating presence = 1 or absence = 0 of breed and genetic marker *p450 GC* and *p450 GG*, respectively. *BFR*, *BW*, and *WW205* are cow specific average 1991 – 1997 performance statistics related to breeding failure rate, average birth and weaning weight, respectively. The baseline scenario reflects a Bermudagrass (BG) pasture system devoid of fescue toxicosis using reciprocal cross cattle with the *p450 CC* genetic marker expression.

Table 6. Observed and Predicted Profitability in \$/hd by Pasture, Breed, and Marker Effects including seasonality (S+), excluding seasonality (S-), and including ownership charges (S+OC).

		Avg. of Explanatory Variables[1]			**Profitability in \$/hd**[2]		
Description	**# of obs.**	BW	BFR	WW205	S+	S-	S+OC
$E^{+,3}$	37	79.7	16.5%	477.5	\$54.56	\$50.61	-\$173.47
BG	49	79.8	17.8%	546.4	\$19.54	\$5.06	-\$208.07
E^+ × *ANGUS*	10	79.2	18.9%	386.3	-\$6.71	-\$9.15	-\$235.21
E^+ × *CROSS*	15	81.8	2.2%	522.8	\$169.64	\$167.73	-\$54.39
E^+ × *BRAHMAN*	12	77.5	32.5%	496.9	-\$38.24	-\$45.99	-\$270.88
BG × *ANGUS*	14	83.2	12.1%	488.4	\$49.83	\$36.23	-\$175.94
BG × *CROSS*	19	78.1	6.8%	571.6	\$119.57	\$101.16	-\$104.92
BG × *BRAHMAN*	16	78.9	35.9%	567.3	-\$125.73	-\$136.33	-\$358.67
E^+ × *ANGUS* × *CC*	3	75.0	4.7%	377.0	\$52.46	\$55.22	-\$171.77
E^+ × *ANGUS* × *GC*	5	81.8	30.0%	395.0	-\$54.81	-\$62.87	-\$286.90
E^+ × *ANGUS* × *GG*	2	79.0	12.5%	378.5	\$24.81	\$28.56	-\$201.10
E^+ × *CROSS* × *CC*	7	83.6	4.7%	529.4	\$153.52	\$149.18	-\$71.23
E^+ × *CROSS* × *GC*	6	80.3	0.0%	528.5	\$184.99	\$181.20	-\$38.73
E^+ × *CROSS* × *GG*	2	80.0	0.0%	482.5	\$177.62	\$179.37	-\$46.09
E^+ × *BRAHMAN* × *CC*	7	76.3	24.1%	499.1	\$10.23	\$8.15	-\$218.60
E^+ × *BRAHMAN* × *GC*	4	81.5	47.0%	485.5	-\$123.61	-\$137.32	-\$362.79
E^+ × *BRAHMAN* × *GG*	1	70.0	33.0%	527.0	-\$31.43	-\$33.91	-\$261.92
BG × *ANGUS* × *CC*	4	83.0	18.8%	480.0	\$1.06	-\$13.32	-\$226.18
BG × *ANGUS* × *GC*	9	82.6	10.4%	488.7	\$63.11	\$49.15	-\$162.38
BG × *ANGUS* × *GG*	1	90.0	0.0%	519.0	\$125.48	\$118.11	-\$96.93
BG × *CROSS* × *CC*	10	79.1	4.0%	562.5	\$141.58	\$122.61	-\$82.16
BG × *CROSS* × *GC*	6	75.7	11.7%	576.8	\$83.24	\$66.39	-\$142.35
BG × *CROSS* × *GG*	3	79.7	6.7%	591.7	\$120.44	\$107.79	-\$103.47
BG × *BRAHMAN* × *CC*	11	80.3	34.7%	577.1	-\$122.45	-\$134.35	-\$354.97
BG × *BRAHMAN* × *GC*	3	75.7	38.0%	560.7	-\$137.24	-\$149.54	-\$372.50
BG × *BRAHMAN* × *GG*	2	76.0	39.5%	523.5	-\$128.79	-\$140.27	-\$361.89

Note:

[1] Birth weight (*BW* in lbs/hd), breeding failure rate (*BFR* as defined in Eq. 1), and weaning weight (*WW205* in lbs/hd averaged across male and female calves per cow) are reported for subsamples meeting the pasture system, breed, and genetic marker characteristics shown in the left most column.

[2] Profitability numbers are observed averages for pasture (E^+, *BG*) and pasture × breed interactions.

[3] E^+ and *BG* represent the presence of endophyte infected tall fescue and Bermudagrass, respectively as the sole feed source on pasture and from hay. *ANGUS*, *BRAHMAN*, *CROSS*, *GC*, and *GG* are variables indicating breed, reciprocal cross, and presence of genetic markers *p450CC*, *p450 GC* and *p450 GG*.

Technical Appendix

Somewhat similar to the linear regression results shown in Table 5 an analysis of variance was conducted in EViews v9 (IHS Global Inc., Irvine, CA) as shown in Appendix Table A1 and Appendix Figure 1.

Appendix Table A1. Analysis of Variance Test for Equality of Means, Observed Means and Estimated Std. Errors for Net Cash Returns (*NR*) in $/hd including Seasonality of Sale Prices by Tall Fescue vs. Bermuda Grass Pasture, Cattle Breed (Angus, Brahman and their reciprocal cross) and Genetic Marker, the p450 C994G SNP, Booneville, AR, 1991-97.

Information Used	**Treatment**	**Mean[1]**	**Std Error**	**model df**	**error df**	**F-value** (p-value)
Pasture	Fescue (E^+)	19.54	23.66	1	84	1.0318
	Bermuda Grass (BG)	54.56	24.31			0.3126
Pasture × Breed	E^+ × Angus (AA)	-6.71	36.31	5	80	11.8439
	E^+ × Cross (AB)	169.64	16.01			<.0001
	E^+ × Brahman (BB)	-38.24	45.64			
	BG × AA	49.83	27.83			
	BG × AB	119.57	23.91			
	BG × BB	-125.73	42.81			
Pasture × Breed × Marker	E^+ × AA × CC	61.87	35.37	17	68	3.6691
	E^+ × AA × GC	-61.04	61.40			0.0001
	E^+ × AA × GG	26.27	48.34			
	E^+ × AB × CC	157.64	33.75			
	E^+ × AB × GC	187.82	9.32			
	E^+ × AB × GG	157.05	4.05			
	E^+ × BB × CC	11.20	44.45			
	E^+ × BB × GC	-126.74	109.36			
	E^+ × BB × GG	-30.29	na			
	BG × AA × CC	-1.97	70.72			
	BG × AA × GC	63.44	29.21			
	BG × AA × GG	134.5	na			
	BG × AB × CC	135.96	17.45			
	BG × AB × GC	85.66	68.00			
	BG × AB × GG	132.72	56.81			
	BG × BB × CC	-122.04	58.76			
	BG × BB × GC	-134.26	90.68			
	BG × BB × GG	-133.22	71.63			

Notes:

1 Arithmetic means are reported for net cash returns defined as cattle and hay sales less cash costs of fuel, fertilizer, twine, medicine and vet services, repair and maintenance, as well as operating interest.

2 Estimated standard errors to use for mean comparisons. Two categories had a single observation.

Appendix Figure 1. Comparison of Mean Net Returns in \$/hd including Seasonality of Sale Prices by Pasture Based Information (A), Pasture × Breed Based Information (B) and Cross Bred Pasture × Marker Information Based Strategies (C) where Pasture was either Tall Fescue or Bermuda Grass, Cattle Breed was either Angus, Brahman or their reciprocal cross, and the Genetic Marker, the p450 C994G SNP could either have the CC, GC, or GG expression, Booneville, AR, 1991-97. Standard errors are not adjusted for birthweight, breeding failure rate and weaning weight impacts and as such are different from those estimated using regression analysis.