Discovery, The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences

Volume 18 Article 8

2017

Cost-benefit Analysis of a Genetic Marker on Cow-calf Operations Differentiated by Pasture and Breed

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Cost-benefit analysis of a genetic marker on cow-calf operations differentiated by pasture and breed

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Abstract

Genetic sequencing in beef cattle (*Bos taurus* L.) is expected to aid producers with selecting breeding stock. Using data from experimental trials conducted with Angus, Brahman, and their reciprocal cross, the single nucleotide polymorphism (SNP) P450 C994G marker expression was investigated for use in selecting genetics suited to grazing endophyte-infected tall fescue (*Festuca arundinacea Schreb.* L.) compared to bermudagrass (*Cynodon dactylon* L.) 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 were either exposed to fungal endophyte-infected (*Acremonium coenophialum* L.) tall fescue grazing and hay or not. The study used the Forage and Cattle Analysis and Planning (FORCAP) decision support software to assess economic performance driven by birth weight, weaning weight, and breeding failure rate differences across treatment. Results suggest that for reciprocal cross herds primarily grazing bermudagrass pastures, the P450 C994C genotype (*CC*) was most favorable; whereas, the P450 G994C genotype (*GC*) was more profitable with tall fescue. Adding genetic market information when selecting a production strategy led to approximately $15/head in added profitability. In comparison to the prorated cost of $2.40/head over the life of a dam, the collection, interpretation, and management of genetic information under the conditions observed in this study may be worthwhile.

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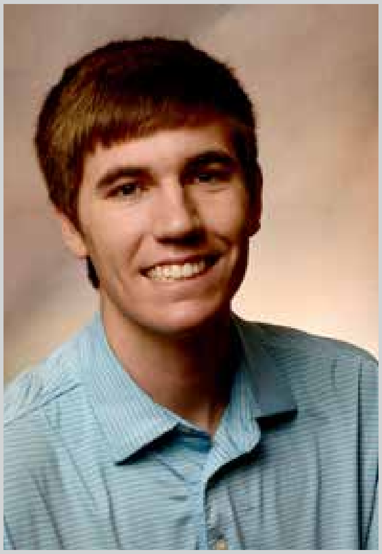
Meet the Student-Author



Josh Crystal

I was born and raised in a very small town near Tulsa, Oklahoma, and graduated from Liberty High School in 2013. Growing up, my family raised whitetail deer, which initiated my interest in agriculture. I first made my way to Arkansas on a golf scholarship at John Brown University in Siloam Springs. After two years, I decided to transfer to the University of Arkansas to return to my farming roots and pursue an agricultural career. During this time, I completed an internship with J.B. Hunt, while also working at Lowe's and for a local veteran. I graduated with honors from Dale Bumpers College of Agriculture with a B.S. in Agricultural Business in May 2017. This fall, I will be pursuing a Master of Business Administration degree through John Brown University's graduate program in Little Rock, Arkansas.

I would like to thank my mentor, Dr. M. Popp, for his relentless effort and guidance while I completed my thesis. I would also like to thank Dr. Rosenkrans and Dr. Kemper for their valuable input and serving on my committee. Most importantly, I give all the glory to God, for without Him, nothing is possible.

Introduction

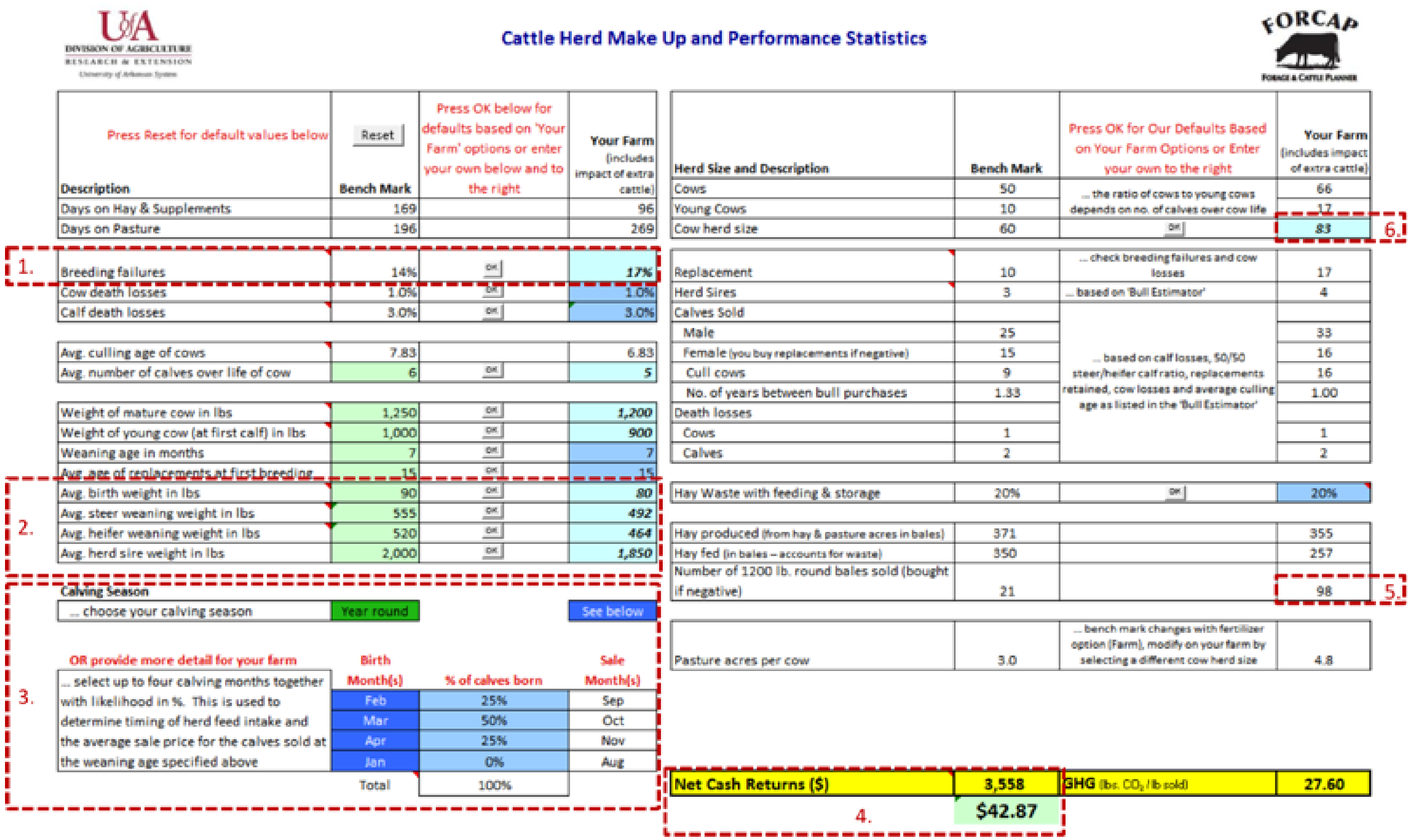
The economics of beef cattle production at the cow-calf level is very much dependent on proper breeding stock selection. Ranchers crossing cattle of different breeds to exploit hybrid vigor, typically select for calving ease with low birth weight and high weaning weight for added revenue potential. However, genetic selection for lower breeding failure rate to enhance herd profitability is more difficult; hence, using genetic markers may be needed. By documenting genetic markers that make up different phenotypes of cattle as expressed by their expected progeny difference (EPD)—which distinguishes cattle of a certain breed to a relative moving average annual baseline standard either within or across breeds for a host of performance statistics (Kuehn and Thallman, 2016a,b)— farmers can make informed choices involving the genetic makeup of their herd. Keeton et al. (2014) used decision support software called the Forage and Cattle Analysis and Planning (FORCAP; Popp et al., 2013) as a tool to evaluate breeds on the basis of EPDs. Choosing genetic marker information, however, is expected to be 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). Whether such decisions are potentially profitable at the cow-calf level, has not been analyzed to a great extent to date especially when dealing with fescue toxicosis occurring in endophyte-infected tall fescue (E^+) pastures (Caldwell et al., 2013; Smith et al., 2012; Johnson et al., 2015).

The objective of this project was to assess whether genetic marker inofrmation would benefit cow-calf operations when they compare the relative profitability of: i) E^+ vs. bermudagrass (*BG*) pasture management strategies; ii) the interaction of pasture management with breed selection of purebred Angus, purebred Brahman or their reciprocal cross to measure the effect of breed selection on pasture utilization; and iii) the interaction of pasture management × breed × genetic marker information.

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 data on spring calves available from 1991 to 1997 under central Arkansas growing conditions. Animals were placed on either E^+ or *BG* pastures and fed hay of similar type. To eliminate sire effects, herd sires were rotated across treatments in 13-d intervals throughout the 75-d breeding period. Lifetime breeding failure rates (BFR) are defined as:

$$\mathrm{BFR} = 1 - \frac{\text{\# of calves born}}{\text{\# of times the cow was bred}} \quad \textit{Eq. 1}$$



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 continuously grazing on 400 acres of pasture and hay supplies met using 125 acres of hay land. Adjusted for each cow were, (1) breeding failure rate (*BFR* defined in Eq. 1) to estimate herd performance if all cows had a specific genetic marker of the experimental cow, (2) birth (*BW*)and weaning weights (*WW205*) 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 that are divided by number of cows (6) exposed to the herd sires. Results shown pertain to an operation using E^{+} pastures and associated average *BFR*, *BW*, and *WW205* as reported in Table 3 for the most commonly observed March calving month. The average reported in Table 3 does not match given effects of averaging over changes in calving month, *BW* and *WW205*, and rounding to nearest calf sales with *BFR*. Unit conversions: 1 ha = 2.4711 acres, 1 lb = 0.4536 kg.

Fig. 1. Sample cattle input interface in the Forage and Cattle Analysis and Planning (FORCAP) program.

In addition to BFR, birth weights, sex of calves and 205-d weaning weight data, calving month, and genetic marker information on the dam were available to perform economic analysis in FORCAP (Fig. 1) to estimate net cash returns per cow (*NR*) holding other operating parameters constant (as summarized in Table 1). As such, *NR* are the revenue from the sale of cattle and excess hay less cash expenses for feed; fertilizer; veterinary and medicine; fuel; repair and maintenance; twine; and operating interest as a measure of relative profitability across individual animals. Further, it is assumed that the performance of a cow could be replicated for a cow with the same genetic marker, breed, and pasture management and thus extrapolated to herd performance of 83 continuously grazing cows, which is a herd size deemed adequate for a farmer to consider obtaining genetic marker information using 125 acres of hay and 400 acres of pasture. Ten-year averages were 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 months (USDA-AMS, 2017) for cattle of different weight (Table 1). Cattle prices were deflated to 2016 dollars using U.S. All Beef Cattle prices (USDA-NASS, 2017a); whereas a fertilizer price index was used on fertilizer price (USDA-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.

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

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

where E^+ is a binary 0/1 variable to observe fescue toxicosis effects ($E^+ = 1$) or alternatively using *BG* without toxins ($E^+ = 0$), *ANGUS* or *BRAHMAN* are similar binary variables indicating breed, *GC* and *GG* indicate the presence or absence of P450 G994C (*GC*) or P450 G994G (*GG*) marker expressions, *BW* and *WW205* are the average birthweight and adjusted 205-d weaning weights of calves born over the life of the cow, respectively. The baseline cow is a reciprocal cross with a P450 C994C (*CC*) marker expression on *BG* pasture and hay as those observations were most frequent. Both *BW* and *WW205* were added as they are key statistics in bull EPDs.

Differences in regression estimates of *NR* across pasture forage, breed, and genetic marker were compared rather than the calculated average of FORCAP-based *NR* as some pasture × breed × marker combinations had very few observations. For example, estimated profitability of the *BG* pasture system with reciprocal cross cattle and the *CC* marker was:

$$NR_{BG,Cross,CC} = a_0 + a_4 \cdot \overline{BFR}_{BG,Cross,CC} + a_5 \cdot \overline{BW}_{BG,Cross,CC} + a_6 \cdot \overline{WW205}_{BG,Cross,CC} \qquad \textit{Eq. 3}$$

where the *a*'s are coefficient estimates from Eq. 2 and $\overline{BFR}$, $\overline{BW}$, and $\overline{WW205}$ are averages from observations pertaining to *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} were used with averages for *BFR*, *BW*, and *WW205* for cattle on E^+. To allow comparisons of *NR* across pasture and pasture × breed, equality of means tests were performed using Welch's F-test.

To have a cow tested for genetic markers, a hair sample can be collected at nearly no cost or a blood sample is estimated to cost $3/head. An additional cost of $8/head is needed for testing. Adding administrative overhead of $1/head, a $12/head cost was prorated over the life of the cow (5 y on average in this study). Profitability gains with breeding stock selection based on breed × pasture × genetic markers compared to breed and breed × pasture selection, thus, needed to exceed $2.40/head for a cow-calf operator to entertain collecting this information.

Results and Discussion

Sales et al. (2011b) focused on the genetic sequence labeled as P450 C994G to determine resistance to E^+ effects on reproductive performance and weight gain in offspring. Economically, drawbacks of E^+ in cattle performance are offset by drought tolerance and persistence of E^+ compared to other non-toxic, cool season grasses which affect feeding and pasture maintenance costs. To combat fescue toxicosis, producers can, for example, seed their pastures to *BG*—free of toxin and heat tolerant—at the cost of added hay feeding when cool season fescue would normally offer grazing opportunities for pasture-fed beef cattle.

This tradeoff is demonstrated at observed average cattle performance statistics for the E^+ and *BG* systems by the wide dark bars in Fig. 2. Using FORCAP, an E^+ system requires 96 d of hay feeding in comparison to 187 d for *BG* pastures in study conditions described above. Hence, using *BG* leads to more hay feeding but also no E^+.

To shed further light on individual cow performance data, regression results for Eq. 2 are shown in Table 2 with the frequency distribution of observations by treatment

Table 1. Prices and costs used by Forage and Cattle Analysis and Planning (FORCAP) decision support software.

Item and Description	Unit	Price	Item and Description	Unit	Price
Livestock			Feed		
4 - 500 lb. steers[†]	$/cwt	170.62	Hay delivered/sold FOB – 5 ft x 5 ft (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[‡]	$/cwt	64.35	Amortized pasture/hay maintenance & establishment[¶]	$/acre	14.00
Purchase price of breeding bull	$/head	2000			
Cull bull[§]	$/cwt	80.77	Fuel use for mowing, raking, and staging	gal/acre	4.50
Beef check off, ins. & yardage	$/head	1.00	Fuel use per day for feeding	gal/83 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	$/head	75	Twine	$/bale	1.00
Caesarian section	$/head	225	Cost for farm vehicle ($/head/month)	$	1.00
Sick treatment (avg. drug charge)	$/head	15	Capital recovery rate[#]	%	5.00
Bull soundness	$/head	30	Operating interest[††]	%	4.75

Notes: Unit conversions needed 1 ha = 2.4711 acres, 1 gal = 3.78 L, 1 ton = 2000 lb, 1 lb = 0.4536 kg, 1 cwt = 100 lbs = 45.36kg

[†] State average, medium and large frame No. 1 prices (USDA-AMS, 2017). 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 user-specified 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.

[‡] 75-80% Lean Breaking Utility.

[§] Yield Grade 1-2, 1000 to 2100 lbs.

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

[#] 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.

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

shown in Table 3. Coefficients were of the expected sign and adjusted 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. Table 3 summarizes calculated FORCAP profitability differences by pasture and pasture × breed, as well as estimated profitability differences by pasture × breed × marker.

As shown in Table 3 and Fig. 3, when comparing E^+ to *BG* forage systems with the average weights and average *BFR*, E^+ forage systems outperform the *BG* system. Given the presence of fescue toxicosis, this is puzzling unless considering the E^+ forage systems' advantage of lesser hay feeding in comparison to *BG* (Fig. 2). 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 even though the ANOVA equality of means test showed no statistically significant differences ($P = 0.31$).

If the producer now adds breed selection to his or her repertoire of decision-making, then the optimal solution is to have E^+ forage with reciprocal cross cattle (Fig. 3B) with

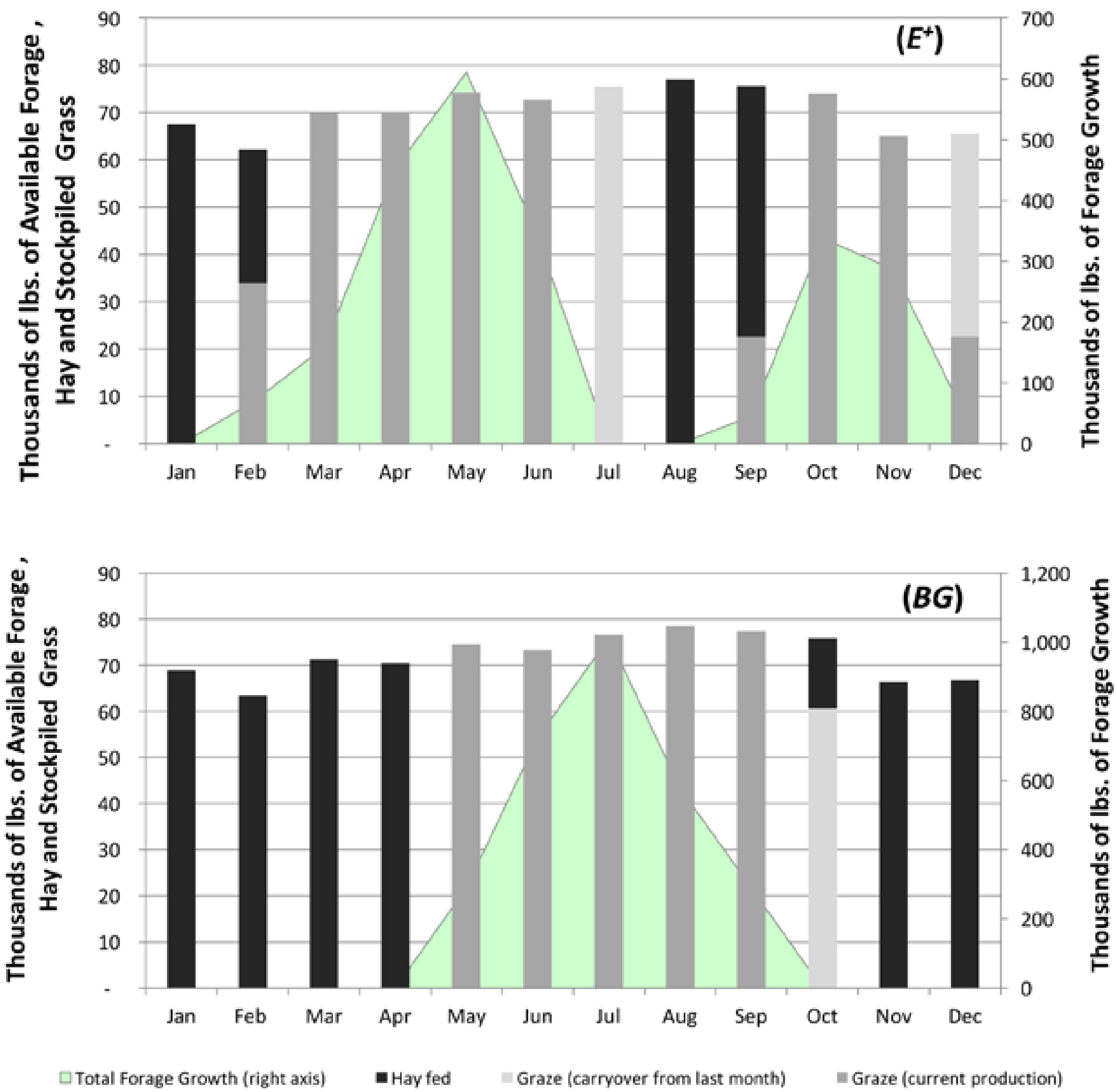


Fig. 2. Forage Balance for Fescue (*E*+) vs. Bermudagrass (*BG*) Pasture Systems as modeled in the Forage and Cattle Analysis and Planning program (FORCAP). Note: Height of bars represents total herd intake requirements. Unit conversion: 1000 lb = 453.6 kg.

hybrid vigor. Angus tend to have lower *BFR* while Brahman deliver higher *WW205* with the reciprocal crosses excelling on both fronts regardless of pasture forage (Table 3). Note that on *BG* systems, weaning weights are higher in the absence of fescue toxicosis. This adds costly hay feeding, and higher weight calves also lead to lower price per 100 lb (cwt) (Table 1). A *BG* × *BRAHMAN* strategy in particular, showed negative cash returns not only because of hay feeding but also high *BFR*. Adding breed information compared to only using pasture system information led to higher returns. Reciprocal cross cattle on E^+ had the highest *NR* at $169.64/head.

Adding genetic marker information on E^+, the optimal solution was to have the *GC* genotype in reciprocal crossed cattle resulting in an estimated *NR* of $184.99/head (Table 3). Negligible *BFR* in conjunction with highest *WW205* when compared to the *GG* genotype that had the same *BFR* showed that lighter *WW205* led to lower cattle revenue. Both the *GG* and *GC* genotypes showed lower *BFR* than the *CC* genotype leading to greater estimated *NR*. Similar to pasture × breed-based results above, the *BG* system was inferior to the E^+ system as higher *WW205* across all markers were not sufficient to offset costs associated with elevated *BFR* with *BG* compared to E^+. Cows with the *CC* genotype performed best on *BG* pastures. This suggested the P450 C994G marker indeed is associated with cattle ability to deal with E^+.

Noteworthy, and not taken into consideration, is the future fate of calves in feedlots starting at lower *WW205* due to their exposure to E^+ pastures. Nonetheless, adding marker information allowed the producer to gain approximately $15 per head per year ($184.99/head with E^+, *Cross*, *GC* vs. $169.64/head on E^+, *Cross*) which is approximately six times the cost of obtaining the added informa-

Table 2. Multivariate regression statistics for forage production, breed, and marker effects.

Variable		Coefficient (Std. Error)	T-Statistic
Constant	a_0	119.79 (43.14)*** †	2.78
$E^{+‡}$	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^+ × *ANGUS*	a_9	50.10 (13.77)***	-3.64
BFR × 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:

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

‡ Dependent variable is individual cow profitability in $/head as estimated in Forage and Cattle Analysis and Planning (FORCAP). 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.

tion. The results are therefore similar to Thompson et al.'s (2014) findings and add to information already reported by Looper et al. (2010) and Sales et al. (2011 a,b).

For future research, a mixed pasture system consisting of both *BG* and E^+ pastures would make an interesting third alternative as that pasture forage species mix is common in many pastures. Further, had genetic marker information been collected on the calves, weaning weight differences could have been analyzed for their effect. Finally, had calves been tracked through the feedlot stage, an overall economic performance to slaughter would have been possible and may favor the *BG* system.

Conclusions

For cow-calf operations using breeds of Angus and Brahman grazing on E^+ or *BG* pastures, the results suggested that the genetic marker analyzed would allow producers to enhance their operation's profitability in comparison to a strategy selection based only on forage type and breed.

Table 3. Observed and predicted profitability in $/head by pasture, breed, and marker effects.

Description	# of obs.	FORCAP Profitability[†] ($/head)	Avg. of Explanatory Variables[‡] *BW*	*BFR*	*WW205*	Est. Profitability[§] ($/head)
E^{+}[¶]	37	$54.56	79.7	16.5%	477.5	na[§]
BG	49	$19.54	79.8	17.8%	546.4	na
E^+ × *ANGUS*	10	-$6.71	79.2	18.9%	386.3	na
E^+ × *CROSS*	15	$169.64	81.8	2.2%	522.8	na
E^+ × *BRAHMAN*	12	-$38.24	77.5	32.5%	496.9	na
BG × *ANGUS*	14	$49.83	83.2	12.1%	488.4	na
BG × *CROSS*	19	$119.57	78.1	6.8%	571.6	na
BG × *BRAHMAN*	16	-$125.73	78.9	35.9%	567.3	na
E^+ × *ANGUS* × *CC*	3	$61.87	75.0	4.7%	377.0	$52.46
E^+ × *ANGUS* × *GC*	5	-$61.04	81.8	30.0%	395.0	-$54.81
E^+ × *ANGUS* × *GG*	2	$26.27	79.0	12.5%	378.5	$24.81
E^+ × *CROSS* × *CC*	7	$157.64	83.6	4.7%	529.4	$153.52
E^+ × *CROSS* × *GC*	6	$187.82	80.3	0.0%	528.5	$184.99
E^+ × *CROSS* × *GG*	2	$157.05	80.0	0.0%	482.5	$177.62
E^+ × *BRAHMAN* × *CC*	7	$11.20	76.3	24.1%	499.1	$10.23
E^+ × *BRAHMAN* × *GC*	4	-$126.74	81.5	47.0%	485.5	-$123.61
E^+ × *BRAHMAN* × *GG*	1	-$30.29	70.0	33.0%	527.0	-$31.43
BG × *ANGUS* × *CC*	4	-$1.97	83.0	18.8%	480.0	$1.06
BG × *ANGUS* × *GC*	9	$63.44	82.6	10.4%	488.7	$63.11
BG × *ANGUS* × *GG*	1	$134.50	90.0	0.0%	519.0	$125.48
BG × *CROSS* × *CC*	10	$135.96	79.1	4.0%	562.5	$141.58
BG × *CROSS* × *GC*	6	$85.66	75.7	11.7%	576.8	$83.24
BG × *CROSS* × *GG*	3	$132.72	79.7	6.7%	591.7	$120.44
BG × *BRAHMAN* × *CC*	11	-$122.04	80.3	34.7%	577.1	-$122.45
BG × *BRAHMAN* × *GC*	3	-$134.26	75.7	38.0%	560.7	-$137.24
BG × *BRAHMAN* × *GG*	2	-$133.22	76.0	39.5%	523.5	-$128.79

Notes: Unit conversion needed 1 lb = 0.4536 kg.

† Calculated net cash returns per head (*NR*) from Forage and Cattle Analysis and Planning (FORCAP) using observed averages for *BW, WW205,* calving month and pasture forage (E^+ or *BG*).

‡ Birth weight (*BW* in lbs/head), breeding failure rate (*BFR* as defined in Eq. 1), and weaning weight (*WW205* in lbs/head 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.

§ Profitability estimates using Eq. 2 coefficients. These estimates are not appropriate (na) for *NR* that vary only by pasture or pasture x breed.

¶ 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*, respectively.

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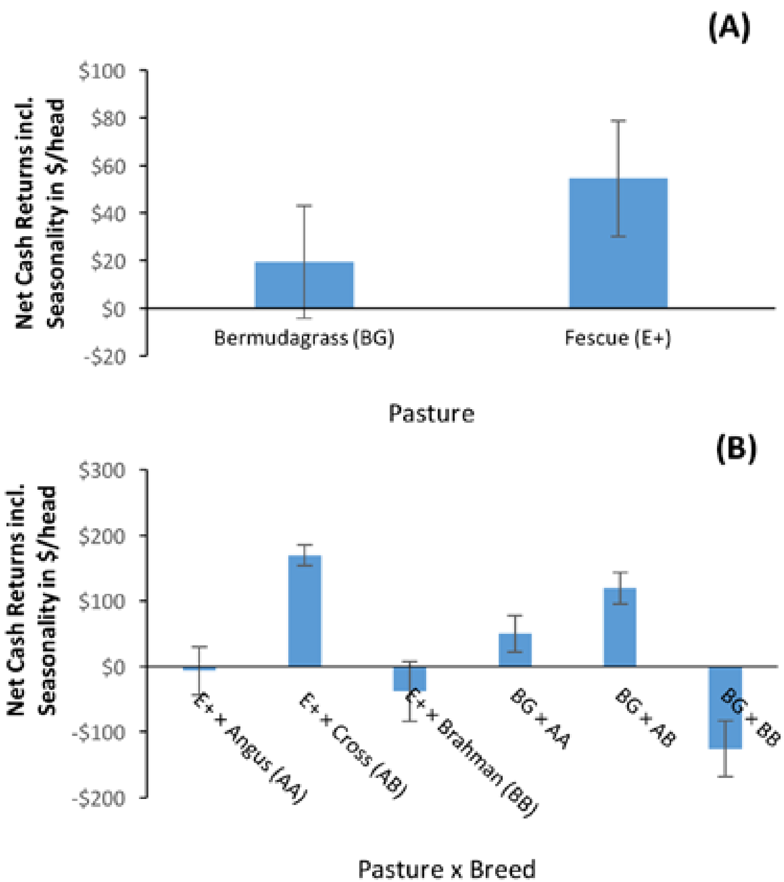

Fig. 3. Comparison of mean net cash returns in $/head as calculated in the Forage and Cattle Analysis and Planning program (FORCAP) including seasonality of sale prices by pasture-based information (A) and pasture- × breed-based information (B) where pasture was either tall fescue or bermudagrass, cattle breed was either Angus, Brahman or their reciprocal cross, Booneville, Ark., 1991-97. Standard errors are not adjusted for birthweight, breeding failure rate, and weaning weight. Pasture differences were not significant ($P = 0.31$) whereas pasture × breed means were significantly different ($P < 0.0001$).

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