18 AUGUST 1971

Performance of Progeny Sired by High and Low Performing Beef Bulls

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First Printing 3M, August 1971

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GROSS AS WELL AS NET RETURNS per calf are dependent upon a combination of price per hundredweight and market weight. Cattlemen need to produce beef calves that are heavier at weaning with sufficient quality to demand top market prices. Performance testing offers a means for measuring inherent differences among beef bulls in conformation and in their ability to grow. Relatively few commercial breeders in Alabama are using above average performance tested bulls. The basis for this statement is the small number of bulls performance tested annually in Alabama and the limited number of commercial and purebred breeders currently enrolled in the Alabama Beef Cattle Improvement Association *(3)*. Less than 6,000 calves are processed annually on the program.

Performance testing is not a new concept. Robert Bakewell and other early livestock breeders used both performance records and progency tests as tools for herd improvement. The early controlled studies reported by Sheets *(10)*, Winters and McMahon *(13)*, Black and Knapp *(1)*, and Knapp et al. *(4)* described differences in performance traits among beef bulls and suggested methods of utilizing these differences in a selection program. Efficiency of gain was considered to be of primary importance and was shown to be closely related to rate of gain in experiments reported by Winters and McMahon *(13)*, Knapp and Baker

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(5), and later by Koch et al. *(7)*. Soon after Knapp and Nordskog *(6)* reported the first estimates of heritability for growth and efficiency of gain, several workers, Patterson, et al. *(8)*, Shelton et al. *(11)*, and Chambers et al. *(2)*, published results of experiments relating performance of beef bulls to performance of their progeny.

The need for information collected under Alabama conditions with reference to the relative merits of bulls with different performance records prompted this study.

EXPERIMENTAL METHODS

This study was conducted from 1958 through 1963 at two locations, the Tuskegee Experiment Field, Tuskegee, Alabama, and the Upper Coastal Plain Substation, Winfield, Alabama, hereafter referred to as Tuskegee and Winfield, respectively. The Main Agricultural Experiment Station, Auburn, Alabama, hereafter referred to as Auburn, conducted the performance tests and furnished all bulls used at both locations. The experimental methods will be described separately for the two locations.

Tuskegee

The brood cows used in this study were grade Herefords developed from common cows of predominately Jersey breeding. The cows were divided into two similar groups of approximately 20 cows each based on age and breeding. They were reallotted each year to minimize differences between cow groups. Culling was based on physical soundness and reproduction. Replacement heifers were selected on the basis of performance and were allotted at random to the breeding groups.

Hereford bulls were used in this study. They were selected each year at the end of the annual performance test. Weaning weight was the primary basis for selecting bulls; however, an effort was made to select bulls with similar conformation scores. Each year, two bulls, one with a high and one with a low weaning weight, were selected to be used the following breeding season. Because of the relationship between weaning weight and post weaning average daily gain (ADG), each high bull had a higher ADG and a higher weight per day of age (WDA) than did the low bull, with the exception of the last year, when ADG was higher for the low bull, Appendix Table 1.

Except during the breeding season, all cows were handled as a single unit to minimize environmental differences between groups. Permanent pastures consisted of pure stands of Coastal bermudagrass and mixed stands of Dallisgrass, common bermudagrass, bahiagrass, and carpetgrass with some crimson and white clover in March and April. Cows were wintered on all the Coastal bermuda hay they would eat and from 1 to 1.5 pounds of cottonseed meal pellets (41 per cent protein) per head daily.

The calving season each year extended from mid-September through February. All calves were weighed and identified by tag at birth. Bull calves were castrated and all calves were dehorned. Calves remained on their dams without creep feed until weaned at an average age of 275 days. Weaning weights and slaughter grades were obtained and all calves except replacement heifers were sold.

Winfield

The brood cows were developed from a group of grade Herefords and Jerseys obtained in 1946. Purebred Hereford and Angus bulls were used after that time with replacement females being retained from succeeding calf crops. At the initiation of this study the herd had been graded up to ¾ or better grade beef cows. Replacement females retained during the experiment were selected on the basis of performance and were allotted at random to the breeding groups. Culling within the cow herds was limited to the removal of non-calving cows and those with physical defects.

Four bulls, two Angus and two Hereford, were selected each year at the end of the annual performance test at Auburn. The high index bulls, one Angus and one Hereford, were heavier at weaning, had a higher ADG on test, and a higher WDA at the end of test than the average of all bulls tested. The low index bulls, one Angus and one Hereford, represented the lower half of their breed for weaning weight, ADG on test, and WDA at the end of test. Efforts were made to select bulls with similar conformation scores. Without exception, the high index bulls were higher in all growth measurements than were the low bulls, Appendix Table 2.

The cow herd was divided into four groups of approximately 20 cows each on the basis of breed, age, and previous record. Except during the breeding season, all cows were handled as a

single unit in order to minimize environmental effects. Permanent pastures consisted of Coastal bermudagrass and dallisgrass-white clover. These pastures were used in sequences, utilizing the white clover in the spring, the Coastal bermuda in the late spring and early summer, and the dallisgrass in late summer and early fall. Cows were wintered on all of the Coastal bermuda hay they would eat plus 1 to 2 pounds of cottonseed meal (41 per cent protein) per head daily.

The calving season extended from September through December. The majority of the calves were born in September and early October. All calves were weighed at birth, identified by ear tag, and had sire, dam, and birth date recorded. All bull calves were castrated at a young age. The calves were maintained on their dams without creep until they were weaned at approximately 10 months of age. Weaning weights and slaughter grades were recorded.

After weaning, all calves were placed on dallisgrass pasture for approximately 90 days. During the second year the calves were supplemented while on pasture with shelled corn at the daily rate of 1 per cent of their body weight. Little benefit was realized from this practice and it was discontinued after 1 year. At the end of the grazing season the calves were again weighed and slaughter grades obtained. Replacement heifers were selected from the two high gaining sire groups. The remaining calves were full fed a blended mixture that contained 33 per cent roughage for an average of 150 days. Due to lack of facilities, all calves were fed in the same lot. At the end of the feeding period, the calves were weighed, graded, and sold for slaughter where limited carcass data were obtained.

Analysis of Data

The data were analyzed by locations using the least-squares procedures. Age of dam was known for calves out of 2, 3, 4, and 5-year-old cows, while all other calves were considered to be out of mature dams. Weaning weights were adjusted to mature-dam equivalent using standard age-of-dam multiplicative factors for the age groups listed above. The adjusted weaning weights thus obtained were used in the analysis. The mathematical model used in the analysis, with the exceptions noted for locations, is shown on page 15. Analyses of variance for the different traits

are shown for Tuskegee and Winfield in Appendix Tables 3 and 4, respectively.

RESULTS AT TUSKEGEE

The average performances of the four high and four low Hereford bulls are given in Table 1. Since these bulls were selected on the basis of weaning weight, the difference of 0.32 pound ADG indicates that selection for weaning weight resulted in increased ability to gain post weaning as well. The difference of 0.44 pound in WDA is economically important, since it reflects the lifetime ability to gain.

TABLE 1. AVERAGE PERFORMANCE OF HEREFORD BULLS USED AT TUSKEGEE EXPERIMENT FIELD, 1958-1961

	High	Low	Difference
Number of bulls	4	4	----
Av. birth wt., lb.	80.8	71.8	9.0
Av. 250 day adj. weaning wt., lb.	576.3	469.7	106.0
Av. daily gain test, lb.	2.48	2.16	0.32
Av. wt. per day age, end test, lb.	2.30	1.86	0.44
Av. conformation score, end test, lb.[1]	11.5	12.2	0.7

[1] 11 = High Good, 12 = low Choice, etc.

Reproductive Performance of Cows

The average reproductive performance of cows bred to high and low bulls is summarized in Table 2. No statistically significant differences in average reproductive performances were noted. However, the breeding season was long (from December 1 to May 15) and the number of cows per bull was small. These conditions favor high per cent calf crops and little, if any, disadvantage would be expected for the smaller bulls.

TABLE 2. REPRODUCTIVE PERFORMANCE OF COWS BRED TO HIGH AND LOW GAINING HEREFORD BULLS AT TUSKEGEE EXPERIMENT FIELD, 1959-1962

	High	Low	Difference
No. of cows exposed	89	86	3
No. of cows calving	79	77	2
Per cent cows calving	88.8	89.5	0.7
No. of calves weaned	75	72	3
Per cent cows weaning calves	84.3	83.7	0.6

Calf Weaning Data

Calves by the high bulls averaged 3 pounds heavier at birth and 13 pounds heavier at weaning than did the calves by the low bulls, Table 3. However, these differences were not statistically significant. In 3 of the 4 years, the average adjusted weaning weights of calves sired by the high bulls were heavier than those sired by the low bulls. In 1960, however, the calves by the low bull averaged 4 pounds heavier than did the calves by the high bull. The difference between calves sired by the high and low gaining bulls is about what would be expected on the basis of heritability estimates (h^2) for weaning weight and the average difference between sires. Since the bull contributes roughly one-half of the inheritance of the offspring and cow groups were considered equal, only one-half of the 106.6 pounds difference between the sire groups should be considered as selection differential (SD). A heritability estimate of 0.3 reported by Warwick *(12)* times 53.3 pounds (SD) yields an expected progeny difference (EPD) in weaning weight of 16 pounds. This agrees rather closely with the 13 pounds actually obtained. Henceforth, the formula will be referred to as EPD = $\frac{1}{2}$ SD x h^2. There was no difference in average slaughter grade between the two groups of calves.

TABLE 3. AVERAGE PERFORMANCE FROM BIRTH TO WEANING OF CALVES SIRED BY HIGH AND LOW WEANING WEIGHT HEREFORD BULLS AT TUSKEGEE EXPERIMENT FIELD, 1959-1962

	High	Low	Difference
No. of calves	75	72	3
Av. birth wt., lb.	68	65	3
Av. 250 day adj. weaning wt., lb.	463	450	13
Av. wt. per day of age, lb.	1.83	1.78	0.05
Av. slaughter grade[1]	8.5	8.4	0.1

[1] 8 = High Standard, 9 = low Good, etc.

RESULTS AT WINFIELD

The average comparative performances of the high and low bulls are summarized in Table 4. There was one each high index Angus and Hereford bull and one each low index Angus and Hereford bull each year for 4 years, a total of 16 bulls. It should be noted that the high index bulls are superior for all growth measurements.

TABLE 4. AVERAGE PERFORMANCE OF ANGUS AND HEREFORD BULLS USED AT UPPER COASTAL PLAIN SUBSTATION, WINFIELD, 1958-1961

	High	Low	Difference
Number of bulls	8	8	---
Av. birth wt., lb.	70	59	11
Av. 250 day adj. weaning wt., lb.	554	486	68
Av. daily gain test, lb.	2.47	1.89	0.58
Av. wt. per day age, lb.	2.24	1.86	0.38
Av. conformation score[1]	11.9	12.3	0.4

[1] 11 = High Good, 12 = low Choice, etc.

Reproductive Performance of Cows

A summary of the reproductive performance of cows bred to the high and low index bulls is given in Table 5. The differences of 4.3 per cent more calves born and 3.2 per cent more calves weaned were not statistically significant. The percentages born and weaned in both the high and low groups were acceptable, particularly since the breeding season was short (90 days) and all bulls were 2-year-olds at the beginning of the breeding season.

TABLE 5. REPRODUCTIVE PERFORMANCE OF COWS BRED TO HIGH AND LOW PERFORMING ANGUS AND HEREFORD BULLS AT UPPER COASTAL PLAIN SUBSTATION, WINFIELD, 1959-1962

	High	Low	Difference
No. of cows exposed	161	153	8
No. of cows calving	148	134	14
Per cent cows calving	91.9	87.6	4.3
No. of calves weaned	142	130	12
Per cent cows weaning calves	88.2	85.0	3.2

Calf Weaning Data

Calves sired by the high bulls were heavier at weaning than were calves sired by the low bulls, Table 6. The difference of 19 pounds is highly significant. Using the same formula as before of EPD = $\frac{1}{2}$ SD x h^2, the expected difference was 10.1 pounds. In comparing the 19 pounds and 10.1 pounds, it should be remembered that selection was based on weaning weight and ADG on test, which results in more accuracy than selecting for weaning weight alone. As expected, there was no difference in slaughter grade at weaning between the two groups.

TABLE 6. AVERAGE PERFORMANCE FROM BIRTH TO WEANING OF CALVES SIRED BY HIGH AND LOW PERFORMING ANGUS AND HEREFORD BULLS AT UPPER COASTAL PLAIN SUBSTATION, WINFIELD, 1959-1962

	High	Low	Difference
No. of calves	137	125	12
Av. birth wt., lb.	62	59	3
Av. 250 day adj. weaning wt., lb.	424	405	19**
Av. slaughter score[1]	8.0	8.1	0.1

[1] 8 = High Standard, 9 = low Good, etc.
** = $P < 0.01$.

Post-Weaning Performance and Carcass Grades

Since the replacement heifers were selected from the high index group at the end of the pasture period, these 20 heifers were not included in the post-weaning data summarized in Table 7. Calves sired by high index bulls gained faster on pasture and significantly faster in the feedlot. The 37 pound weight advantage at the end of the feedlot period was highly significant. For the 3 years that carcass data were available, there was a significant difference of 16 pounds more carcass from calves sired by high index bulls. There was no difference in grade between the two groups of carcasses.

TABLE 7. AVERAGE POST-WEANING PERFORMANCE OF PROGENY SIRED BY HIGH AND LOW GAINING ANGUS AND HEREFORD BULLS AT UPPER COASTAL PLAIN SUBSTATION, WINFIELD, 1960-1963

	High	Low	Difference
No. of calves	117	124	----
Av. gain on pasture, lb.	60	56	4
Av. gain in feed lot, lb.	286	269	17*
Av. final wt., lb.	830	793	37**
Av. carcass wt., lb.[1]	484	468	16*
Av. carcass grade[2]	10.5	10.5	0

[1] Only 3 years. Carcass data should not be related to final weight.
[2] 10 = Average Good, 11 = high Good, etc.
* = $P < 0.05$.
** = $P < 0.01$.

DISCUSSION

Progeny testing is the most accurate method of identifying inherent differences in performance traits among beef sires. However, because of the time involved and the number of offspring required for a progeny test, performance testing is usually used to initially rank prospective sires. The relative accuracy of rankings is dependent on the heritability of the trait under considera-

tion. Heritability estimates for weaning weight are lower than those reported for post-weaning gain. Average estimates of 0.30 and 0.45, respectively, were reported by Warwick *(12)*.

Results of the two studies reported here indicate that performance records are useful in selecting herd bull replacements. The high bulls used at Tuskegee averaged 106.6 pounds heavier at weaning than the low bulls. The difference is compared to an average of 13 pounds heavier calves sired by the high bulls. These values are compared to average differences of 67.6 pounds between sire groups and 19 pounds between sire progeny groups at Winfield. Both values are reasonable when it is remembered that selection was based on weaning weight for the bulls used at Tuskegee and on weaning weight, ADG, and WDA for the bulls used at Winfield. In addition, heritability is lower for weaning weight than for ADG. In neither study was selection applied to the cow groups.

The post-weaning gain difference of 17 pounds at Winfield is reasonable, and the formula EPD = ½ SD x h^2, yields a value of 18 pounds. Accumulating the differences for weaning weight, pasture gain, and feedlot gain resulted in a total of 37 pounds extra weight at the same age. At a constant price of $28 per hundredweight this extra 37 pounds is worth $10.36. A high index bull bred to 30 cows with 87 per cent calf crop weaned, Table 5, would produce $269.36 greater gross returns per year. Projecting a normal useful life expectancy of 6 years, this would total $1,616.16. Admittedly, not all of this difference is profit. However, cost of maintenance and production should be approximately the same for the two groups with the exception of the feedlot period. Since calves by the high index bulls gained more, they presumably consumed more feed, but even then, research reports *(13, 5, 7)* have shown these gains to be more economical. Perhaps of equal importance is the increased value of replacement heifers sired by the high index bull.

The Tuskegee calves were sold at weaning. However, if the same values are applied, the 13 extra pounds at weaning at $28 per hundredweight is worth $3.64. For a bull unit of 30 cows weaning 26 calves per year for 6 years, an advantage of $567.84 is projected for the high gaining bull.

An analysis was made of sales records of the annual Auburn University Performance Test Bull Sale by Patterson and McGuire *(9)*. Using this method of calculation, the high performing

bulls used at Tuskegee would have cost $246.86 per bull more than the low performing bulls. The high index bulls at Winfield would have cost $275.71 per bull more than the low index bulls. Assuming these values to be approximately correct, the high performance bulls used at Tuskegee are worth $320.98 more over their lifetime than the low performing bulls. On the other hand, the high performing bulls at Winfield were estimated to be worth $1,340.45 more than the low performing bulls. This resulted primarily from two causes. First, there was an increase in accuracy of selection of the bulls because more than one measure of growth was considered in the selection index. In addition, the calves were finished in the feedlot and therefore had a greater opportunity to express their superior inheritance for rapid, efficient growth.

SUMMARY

Performance tested bulls were progeny tested at two locations with the following results obtained: (a) Calves sired by bulls with heavy weaning weights were 13 pounds heavier at weaning than those sired by bulls with low weaning weights at Tuskegee; and (b) Calves sired by high index bulls weaned 19 pounds heavier, gained 4 pounds more on pasture, gained 17 pounds more in feedlot, and had 16-pound heavier carcasses than did calves by low index bulls at Winfield.

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APPENDIX

APPENDIX TABLE 1. PERFORMANCE OF BULLS USED AT TUSKEGEE EXPERIMENT FIELD, 1958-1961

Year used	Group	Birth wt.	Adjusted weaning wt.	ADG on test	WDA end of test	Conf. score end of test[1]
		Lb.	*Lb.*	*Lb.*	*Lb.*	
1958	High	90	645	2.38	2.26	11
1959	High	81	615	2.48	2.27	13
1960	High	80	535	2.79	2.35	11
1961	High	72	510	2.25	2.32	11
Av.	High	80.8	576.3	2.48	2.30	11.5
1958	Low	77	539	1.86	1.67	12
1959	Low	66	465	2.14	1.81	13
1960	Low	79	415	2.07	1.91	11
1961	Low	65	460	2.59	2.04	13
Av.	Low	71.8	469.7	2.16	1.86	12.2
Diff.	-----	9.0	106.6	0.32	0.44	0.7

[1] 11 = High Good, 12 = low Choice, 13 = Choice, etc.

APPENDIX TABLE 2. PERFORMANCE OF BULLS USED AT UPPER COASTAL PLAIN SUBSTATION, WINFIELD, 1958-1961

Year used	Breed	Group	Birth wt.	Adjusted weaning wt.	ADG on test	WDA end of test	Conf. score end of test[1]
			Lb.	*Lb.*	*Lb.*	*Lb.*	
1958	Angus	High	72	555	2.64	2.09	12
1959	Angus	High	71	585	2.11	2.10	11
1960	Angus	High	60	565	2.38	2.33	12
1961	Angus	High	56	590	2.21	2.43	12
Av.	Angus	High	64.8	573.7	2.34	2.24	11.8
1958	Angus	Low	57	530	1.66	1.81	11
1959	Angus	Low	48	460	1.91	1.71	13
1960	Angus	Low	67	535	2.14	2.12	13
1961	Angus	Low	57	460	2.01	1.89	13
Av.	Angus	Low	57.2	496.2	1.93	1.88	12.5
Diff.	-----	-----	7.6	77.5	0.41	0.36	—0.7
1958	Here.	High	73	595	2.82	2.29	13
1959	Here.	High	81	555	2.66	2.15	12
1960	Here.	High	71	485	2.54	2.17	11
1961	Here.	High	77	505	2.38	2.37	12
Av.	Here.	High	75.5	535.0	2.60	2.24	12.0
1958	Here.	Low	58	450	1.75	1.60	12
1959	Here.	Low	68	545	1.82	1.92	14
1960	Here.	Low	54	445	1.89	1.79	11
1961	Here.	Low	68	470	1.94	2.03	12
Av.	Here.	Low	62.0	477.5	1.85	1.84	12.2
Diff.	-----		13.5	57.5	0.75	0.40	—0.2

[1] 11 = High Good, 12 = low Choice, 13 = Choice, etc.

APPENDIX TABLE 3. ANALYSIS OF VARIANCE FOR WEANING WEIGHT AND SLAUGHTER SCORE TUSKEGEE EXPERIMENT FIELD

Source	df	Mean squares for traits	
		Weaning weight	Slaughter score
Index	1	6,922.3	0.23
Sex	1	19,346.0*	0.36
Year	3	11,696.0*	5.90
Index x sex	1	131.7	3.47
Index x year	3	1,671.3	1.65
Sex x year	3	4,966.5	2.38
Regression	1	136,830.0**	22.13**
Error	133	3,862.1	2.04

* = $P < 0.05$.
** = $P < 0.01$.

The mathematical model used for analysis is as follows:[1]

$$Y_{ijklm} = \bar{\mu} + I_i + B_j + S_k + Y_l + IB_{(ij)} + IS_{(ik)} + IY_{(il)} + BS_{(jk)} + BY_{(jl)} + SY_{(kl)} + b_{(X_{ijklm} - \bar{x}_{ijklm})} + eijklm$$

where: Y_{ijklm} is the observation of the m-th calf in the $ijkl$-th class,

$\bar{\mu}$ is the theoretical mean when all subclasses have equal numbers and date of birth equal zero,

I_i is the deviation of the i-th index from the overall mean,

B_j is the deviation of the j-th breed from the overall mean,[2]

S_k is the deviation of the k-th sex from the overall mean,

Y_l is the deviation of the l-th year from the overall mean,

$IB_{(ij)} \ldots . SY_{(kl)}$ is the individual interaction effects expressed as a deviation from the overall mean,

$b_{(X_{ijklm} - \bar{x}_{ijklm})}$ is the partial regression coefficient of the $\mu ijklm$ on $(X_{ijklm} - \bar{x}_{ijklm})$,

where: μ_{ijklm} is the m-th calf in the $ijkl$ subgroup, and

X_{ijklm} is the birthdate of the same calf, and

$\bar{x}_{ijklm}$ is the mean birthdate of the calves in the $inkl$ subgroup, and

$eijklm$ is random error.

[1] Personal communication, John A. McGuire, Assistant Professor, Research Data Analysis, Auburn University.

[2] Only one breed was used at the Tuskegee Experiment Field; therefore, breed and all interactions were eliminated from the model used to analyze these data.

APPENDIX TABLE 4. ANALYSIS OF VARIANCE FOR WEANING WEIGHT, SLAUGHTER SCORE, PASTURE ADG, FEED LOT ADG, FINAL WDA, CARCASS WDA, AND CARCASS GRADE, UPPER COASTAL PLAIN SUBSTATION, WINFIELD

Source	df	Mean squares for traits						
		Weaning weight	Slaughter score	Pasture ADG	Feedlot ADG	Final WDA	Carcass WDA[3]	Carcass grade[3]
Index	1	30,420.0**	0.87	0.17	0.56*	0.15**	0.04*	0.29
Breed	1	6,237.7	17.11**	0.22*	0.01	0.00	0.02	15.84**
Sex	1	98,855.0**	1.56	0.06	0.15	0.67**	0.18**	3.12
Year	3	9,888.1*	54.07**	1.77**	4.93**	0.19**	0.06**	21.55**
Index x breed	1	806.6	0.88	0.03	0.10	0.02	0.01	7.98*
Index x sex	1	70.6	0.03	0.05	0.05	0.00	0.00	0.50
Index x year	3	12,199.0*	3.75	0.04	0.18	0.02	0.02	3.23
Breed x sex	1	7,878.8	0.35	0.00	0.07	0.03	0.00	2.64
Breed x year	3	929.2	0.25	0.04	0.04	0.02	0.00	4.97
Sex x year	3	3,168.6	4.03	0.01	0.10	0.02	0.00	0.37
Regression[1]	1	159,650.0**		0.01	0.00	0.01	0.01	
Error[2]	242	3,478.5	1.87	0.06	0.10	0.02	0.01	2.09

[1] Regression analysis was not used for score and carcass grade.

[2] Error df was 242, 243, 242, 221, 221, 174 and 174 for weaning Weight, Slaughter Score, Pasture ADG, Feedlot ADG, Final WDA, Carcass WDA and Carcass Grade, respectively.

[3] Only 3 years available; therefore, df for Year, Index x Year, Breed x Year and Sex x Year equals 2.

* $P < 0.05$.

** $P < 0.01$.