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MORE INFORMED COMMERCIAL ANGUS REPLACEMENT HEIFER DECISIONS WITH GENEMAX[®] ADVANTAGE[™]

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KEY POINTS

- GeneMax[®] Advantage[™] is a genomic test for prospective commercial Angus replacement females that are 75% or greater Black Angus breed composition
- GeneMax Advantage delivers three economic index scores (Cow, Feeder and Total), genomic predictions for ten individual traits, customizable outlier reporting for three threshold traits – all benchmarked against 57,260 tested commercial Angus replacement heifer candidates – as well as Sire Match to registered and transferred HD 50K and i50K tested Angus sires
- GeneMax Advantage predictions are based on marker effects derived from the single-step Angus National Cattle Evaluation (NCE) implemented July 7, 2017 by Angus Genetics Inc. (AGI), and primarily enabled by Angus breeder adoption of genomic testing (335,000 animals with genotypes)
- Along with GE-EPDs used to inform Angus bull buying, GeneMax Advantage is intended to provide commercial users of Angus with the most advanced genetic information possible for making selection, breeding and marketing decisions, including feeder cattle price discovery for untested herd mates

INTRODUCTION

Replacement heifer selection and breeding decisions are challenging and economically impactful for commercial cow-calf producers. Replacement costs for heifers and bulls typically rival annual feed costs as the two highest ranking sources of expense. Typically, based on little more than visual appearance, commercial producers decide whether candidate heifers are likely to become profitable cows long before they've had the opportunity to express genetic merit for sustained maternal productivity, as well as transmit genetics for feedlot and carcass performance to feeder progeny. Selected replacements that populate the cow inventory also comprise one-half of the genetic merit of future candidate replacements. Hence, the duration and magnitude of related production expenses and revenues make it especially beneficial to select and develop heifers with the greatest genetic potential.

GeneMax[®] Advantage[™] results are intended to complement other sources of information that may be used in commercial heifer selection and breeding, such as phenotypic evaluation, age, and dam productivity. Genomic predictions for individual traits, multiple-trait economic indexes, customizable identification of genetic outliers and Sire Match features included in GeneMax Advantage provide valuable insight into the genetic potential of candidate replacement heifers, particularly for traits that are otherwise difficult, time consuming and expensive to measure using traditional methods. Sources of value return from testing go beyond more profitable selection decisions, to also include more complementary lifetime natural service and A.I. breeding (bull and semen buying), as well as more informed price discovery for feeder cattle mates and progeny of tested females. What's more, GeneMax Advantage predictions are updated annually and re-reported to customers to reflect the most accurate aggregate marker effects derived from the Angus seedstock population, evolving economic assumptions and expanded reference population.

PRODUCT DEVELOPMENT AND DESCRIPTION

Zoetis, Angus Genetics Inc. (AGI) and Certified Angus Beef[®] (CAB) are pleased to offer GeneMax Advantage as the premier commercial Angus heifer selection tool for cow-calf producers. Designed for use in 75% and greater commercial Angus (black) candidate replacement females, GeneMax Advantage extends the simplicity of the GeneMax[®] Focus[™] brand to a more comprehensive suite of traits and features.

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GeneMax Advantage trait predictions are based on marker effects derived from AGI's single-step Angus NCE implemented July 7, 2017¹. Generally, Single-Step refers to streamlined methods for integrating genomic information into NCE through use of truer genomic-informed pedigree relationships between animals across the evaluated population. This inaugural single-step evaluation included 335,000 animals with high-density genotypes – primarily HD 50K and i50K tested Angus seedstock – as compared to less than one-third as many genotyped animals (108,000) in the previous version-5 calibration of marker effects.

The Angus single-step evaluation also included updated genetic parameters and modernized multiple-trait genetic evaluation models that incorporated millions-more genetically correlated weaning weight records in the evaluation of birth and carcass weight as well as carcass composition traits. Incorporation of such weaning records also better accounted for selection/culling bias introduced when some animals are not evaluated beyond weaning age. Together, single-step integration of over three times more genomic information, updated genetic parameters and modernized multiple-trait models, resulted in more explained genetic variation and informative genomic breeding values for this latest version of GeneMax Advantage.

It follows that with these broad-sweeping advancements, genomic predictions from single-step that drive the latest GeneMax Advantage trait and index predictions rank commercial Angus females somewhat differently than the previous version-5 calibration. For the ten individual trait predictions included in GeneMax Advantage, the average correlation between single-step and version-5 predictions was .65, with a high of .81 for marbling. The same correlations for GeneMax Advantage index scores were .48, .68 and .58 for Cow, Feeder and Total Advantage, respectively.

The efficacy of the back-solved genomic breeding values from single-step can generally be characterized through the resulting accuracy and progeny equivalents associated with GE-EPDs for non-parent Angus seedstock (Table 1). While GeneMax Advantage predictions do not include pedigree information which contributes to added accuracy for GE-EPDs, the majority of progeny equivalents listed for each trait are driven by genomic information. As such, for most traits included in GeneMax Advantage, the dependability of predicted genetic merit exceeds what otherwise would require more than a lifetime of progeny performance records included for dams in conventional genetic evaluation.

TABLE 1: Angus GE-EPDs from single-step – Trait Heritability estimates, accuracy values and progeny equivalents¹

Trait	Updated Heritability	Accuracy of GE-EPD ^a	Approximate Progeny Equivalents ^a	Average Progeny Equivalents by Trait Group
Heifer Pregnancy (HP)	.15	.20	14	20 Daughters
Calving Ease Maternal (CEM)	.20	.30	20	
Calving Ease Direct (CED)	.19	.36	28	
Birth Weight (BW)	.43	.48	21	
Milk	.12	.36	33	
Docility (Doc)	.44	.34	10	
Scrotal Circumference (SC)	.48	.40	13	
Weaning Weight (WW)	.20	.42	26	14 Progeny
Yearling Weight (YW)	.24	.38	21	
Yearling Height (YH)	.51	.39	11	
Dry Matter Intake (DMI)	.36	.24	8	
Mature Weight (MW)	.37	.31	11	
Mature Height (MH)	.62	.36	8	
Carcass Weight (CW)	.44	.32	9	10 Carcasses
Marbling (Marb)	.48	.34	9	
Ribeye Area (RE)	.32	.30	12	
Fat	.33	.29	11	

^aApproximate progeny equivalents associated with the accuracy of GE-EPDs based on verified pedigree and genomic information and without an individual performance record. Progeny equivalents for carcass traits are actual progeny carcass records—equates to ultrasound scans from approximately 30 progeny.

GENEMAX ADVANTAGE INDIVIDUAL TRAIT SCORES

As mentioned, GeneMax Advantage includes genomic predictions for ten individual traits that are drivers of the Cow, Feeder and Total Advantage indexes. For easier interpretation, these predictions are reported as normally distributed transformed scores ranging from 1 to 100. Scores of roughly 50 represent average genetic merit for each trait as benchmarked against the reference population of tested commercial Angus females (n=57,260). The scores indicate both the rank of predicted merit (Table 2), as well as magnitude of underlying genetic difference (Table 3). Individual trait scores also help explain specific sources of index value and are intended to help refine selection, mating and marketing decisions (discussed later).

Generally, higher GeneMax Advantage scores equate to more favorable underlying molecular breeding values for most traits. Exceptions include scores for milk and mature cow weight, where intermediate scores typically represent more optimum levels of genetic potential and associated feed requirements suitable for many operations. Information in Table 3 serves as a general guide to interpreting trait and index scores and underlying magnitude of genomic breeding values and dollars of index merit for every 10 score units. As an example, if selected heifers have scores for Heifer Pregnancy that average 30 units higher than non-selected heifers, they are predicted to be 7.5% more likely to conceive during the first breeding season ($3 \times 2.5\% = 7.5\%$).

TABLE 2. Minimum GeneMax Advantage trait and index scores associated top percentile rankings.

Top Percentile Ranking	Minimum Score
1	88
5	82
10	77
20	68
30	61
40	55
50	49
60	37
70	30
80	22
90	22
95	16

TABLE 3: GeneMax Advantage trait scores, interpretation and underlying MVP per ten score units

Trait Score	Score Interpretation	MVP / 10 Trait Score Units
Calving Ease Maternal	Higher Score - Easier Calving	4.2% probability
Weaning Weight	Higher Score - Heavier	11 lbs.
Heifer Pregnancy	Higher Score - Higher Probability	2.5% probability
Milk	Higher Score - More Milk	6 lbs.
Mature Weight	Higher Score - Heavier	22 lbs.
Cow Advantage Score	Higher Score - More Profit	\$21.83/calf
Post-Weaning Gain	Higher Score - Higher Gain	9 lbs.
Carcass Weight	Higher Score - Heavier	14 lbs.
Marbling	Higher Score - More Marbling	.25 score units
Ribeye Area	Higher Score - Larger Ribeye	.22 in ²
Fat Thickness	Higher Score - Less Fat	-.24 in
Feeder Advantage Score	Higher Score - More Profit	\$10.68/calf
Total Advantage Score	Higher Score - More Profit	\$27.54/calf
Cow Cost Score	Outlier Trait	\$12.04/calf

GENEMAX ADVANTAGE ECONOMIC INDEX SCORES

GeneMax Advantage translates the multi-trait genetic merit of tested heifers using three index predictors of profit potential across production phases. These economic scores were derived using classic selection index methodology and are intended to *simplify* multiple-trait selection. The economic assumptions (i.e., input costs, output prices/value) were derived from various industry sources, are aligned with the assumptions used by AGI for dollar-value indexes, and generally represent the most recent three-year averages.^{2,8} The weights applied to trait predictions were calculated based on these economic inputs, and adjusted for their respective genetic variances and correlations.

Similar to individual trait scores, the resulting index values are transformed to the normally distributed 1 to 100 scale for easy ranking, interpretation and use in selection. Again, higher scores equate to more desirable net return, with scores of 50 representing average combined genetic merit as benchmarked against the reference population of 57,260 tested commercial Angus females. As an example, if selected heifers have Total Advantage scores that average 30 units higher than non-selected heifers, expected net returns are just over \$82 per calf ($3 \times \$27.54 = \82.62), or roughly \$495 higher over the first six calf crops.

GeneMax Advantage extends the simplicity of the GeneMax® Focus™ brand to a more comprehensive suite of traits and features.

The three GeneMax Advantage indexes include the following economically weighted traits:

- Cow Advantage index scores rank candidate replacements for net return from combined genetic merit for heifer pregnancy, calving ease maternal and direct (includes birth weight), direct and maternal (milk) weaning weight, as well as associated costs of production due to differences in mature cow size and milk production, while also accounting for variation in cull cow value.
- Feeder Advantage index scores rank candidate replacements for net returns from combined genetic merit transmitted to progeny for yearling growth (post-weaning gain), carcass weight and grade (USDA Quality and Yield Grades as predicted by component traits), and costs of feedyard gain due to genetic differences in dry matter intake.
- Total Advantage index scores rank candidate replacements for net returns from combined genetic merit across all economically relevant traits captured in the Cow and Feeder Advantage indexes. As such, this is the one most simple and comprehensive prediction of system-wide production efficiency upon which to primarily base selection and breeding decisions.

The relative contributions of different trait groupings to each index are illustrated in Figures 1, 2, 3 and 4. It is useful

FIGURE 1. Relative contributions of trait groupings to Cow Advantage index scores

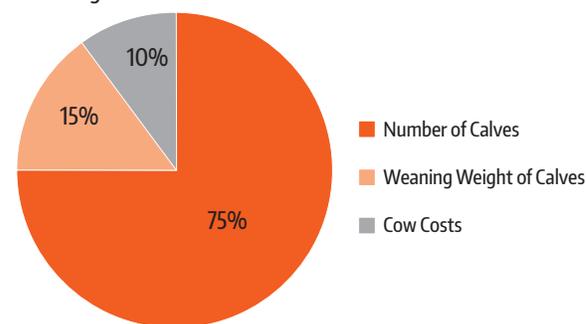


FIGURE 2. Relative contributions of trait groupings to Feeder Advantage index scores

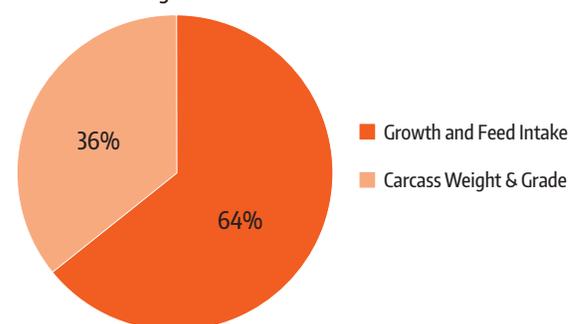


FIGURE 3. Relative contributions of trait groupings to Total Advantage index scores

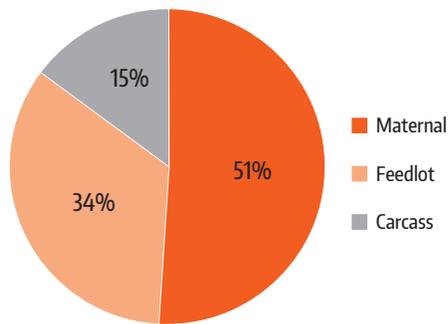
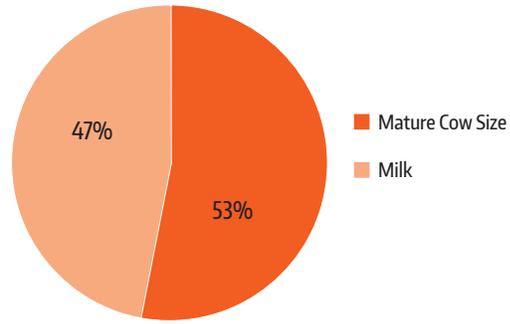


FIGURE 4. Relative contributions of trait groupings to Cow Cost outliers



to note that Cow, Feeder and Total index scores are calculated separately and independent from one another. Total Advantage index scores are more highly correlated to Cow as compared to Feeder scores (.90 versus .62). As should be expected, the relationship between Cow and Feeder index scores is lower (.32), because beyond growth notably different traits drive net returns for these separate phases of production. Predictions for cow cost were negatively (favorably) associated with Cow, Feeder and Total Advantage index scores (correlations ranging from -.05 to -.25). The intention of these indexes is to simplify appropriate multiple trait selection and breeding decisions to optimize herd-wide genetic potentials across traits that ultimately impact both revenues as well as costs of production.

ASSOCIATIONS BETWEEN GENEMAX ADVANTAGE INDEX SCORES, EXPECTED NET RETURNS AND IMPROVEMENTS IN INDIVIDUAL TRAITS

Females with higher Cow Advantage Scores are anticipated to produce more calves and financial return at weaning due to more desirable genetic merit, expressed through heifer pregnancy and calving ease, as well as growth and optimum levels of milk and cow size. Females with higher Feeder Advantage Scores are expected to produce feeder calves with greater post-weaning profit potential attributed to superior feedlot rate and cost of gain, increased carcass weight, and higher carcass Quality and Yield Grade premiums. Females with greater Total Advantage scores are expected to be more profitable over their lifetimes due to all evaluated facets of maternal, feedlot and carcass production efficiency.

Cow, Feeder and Total Advantage scores are driven by differences in underlying genetic merit expressed in net dollars for combinations of traits mentioned above, weighted according to economic impact. Ten (10) points of difference in Cow, Feeder and Total Advantage Score represent \$21.83, \$10.68 and \$27.54 respective predicted difference in net return per calf for typical cow-calf operations. These economic benefits from selection are largely applicable to each annual calf crop, and accumulate throughout the productive lives of selected females. The notable exceptions are economic values assigned to genetic merit for heifer pregnancy and maternal calving ease which have greater impact on the first calf crop. However, benefits in these traits and others are also realized from future heifer progeny retained out of genetically superior dams, and their respective offspring. Accumulative value return from selection based on Total Advantage Score has been estimated to be upwards to \$400 per retained female¹⁰. Additional sources of value return include more informed mating decisions (and associated bull buying), as well as from feeder cattle marketing programs that incorporate genetic information for price discovery.

When using indexes to simplify selection, it is useful to understand relationships between index values and predictions for individual traits. Correlations between GeneMax Advantage indexes and underlying genomic breeding values are provided in table 4, and help breeders gauge the direction and magnitude of selection pressure and

response in individual traits that is expected from selection using the corresponding index. For example, correlations between genomic breeding values for growth traits are high with Feeder Advantage Score, notably lower with Cow Advantage Score where heifer pregnancy and calving ease maternal are more important drivers, and intermediate with Total Advantage Score where simultaneous improvement across more traits is the objective. These correlations can also help to inform breeders where more or less selection and mating attention may need to be exercised using individual trait predictions.

TABLE 4: Correlations between GeneMax Advantage index scores and Molecular value predictions as evaluated in the reference population of commercial angus females (N=57,260)⁹

Trait	Total Advantage	Cow Advantage	Feeder Advantage
Calving Ease Direct	.09	.07	.08
Birth Weight	.08	.04	.14
Weaning Weight	.60	.29	.86
Post-Weaning Gain	.42	.22	.91
Dry Matter Intake	.15	.08	.21
Yearling Height	.14	.11	.17
Scrotal Circumference	.20	.13	.23
Docity	.17	.06	.30
Heifer Pregnancy	.51	.58	.13
Calving Ease Maternal	.61	.79	.00
Milk	.18	.06	.05
Mature Weight	.12	.03	.34
Mature Height	.11	.03	.23
Carcass Weight	.42	.24	.64
Marbling	.20	.03	.38
Ribeye Area	.21	.11	.36
Fat	.09	.06	.05

OUTLIERS IDENTIFIED IN SMART REPORTING

While GeneMax Advantage indexes quantify predicted differences in profitability, additional traits often warrant special consideration and impact returns in specific environments and production scenarios. This includes traits that are difficult to define as to their economic impact, and traits that may augment selection and mating for specific situations. To help producers readily identify potential undesirable outlier animals for higher cow cost (due to cow size and milk), docity and tenderness, customizable thresholds and reporting are available through secured AGI customer

login. Customers set the desired limits of ranking as benchmarked against the reference population for these traits, and then animals with genetic predictions that fall outside tolerable thresholds are flagged with a minus (-) sign.

- Cow Cost – High cow maintenance and production feed costs associated with genetics for combined mature cow size and milk (default flags animals that rank in the most expensive 5%) – more stringent thresholds for maximum acceptable cow costs (i.e. most expensive 20%) are suggested for matching size and milk to sparse and/or expensive feed resources
- Docility – Females with less desirable docility/temperament (default flags animals that rank in the most undesirable 5% for nervous behavior) – in cases where labor, facilities and ease of handling necessitate calmer disposition, identifying a wider range of undesirable temperament to help inform culling or corrective mating is recommended
- Tenderness – Least desirable for tenderness as determined by genomic predictions for Warner-Bratzler shear force (default is least desirable 5%) – as consumer targets for overall palatability impacted by tenderness, juiciness and flavor intensify (the latter two impacted by marbling), added attention to tenderness in addition to marbling may be justified

AVAILABLE SIRE MATCH ENABLED

GeneMax Advantage also matches potential Angus sires to tested heifer progeny. A requirement for this feature is for bulls to be registered with the American Angus Association and transferred at the time of sale to the AGI account of the customer requesting GeneMax testing. This important feature allows producers with genomic tested Angus bulls to proactively manage inbreeding when mating tested heifers, while still providing the flexibility of multi-sire breeding systems, and combined use of artificial insemination and natural service breeding. Inbreeding has generally been documented to adversely affect reproductive, survival and fitness traits. Ideally, customers are advised to designate candidate sires with their AAA registration numbers at time of order submission. In cases where candidate sires have not yet been genomic tested, or if ownership has not yet been transferred at the time heifers are tested, Sire Match may be requested following initial delivery of GeneMax Advantage results.

GeneMax Advantage provides flexibility in replacement heifer selection and a wealth of information for mating and marketing decisions.

USE OF GENEMAX ADVANTAGE IN BREEDING DECISIONS

GeneMax Advantage provides flexibility in replacement heifer selection and a wealth of information for mating and marketing decisions. While Total Advantage provides a simple and comprehensive assessment of an individual heifer's future contribution to supply chain profitability, there are instances where other Advantage indexes and individual trait predictions may be more applicable and used to inform mating. For example, in instances where environmental constraints put a premium on cow adaptability, use of Cow Advantage Scores coupled with heifer pregnancy and close attention to Cow Cost outliers to inform bull buying based on GE-EPDs for these traits, will help match genetic potentials of future heifer calf crops to feed resources. Alternatively, for producers with abundant feed

resources and the opportunity to benefit directly from feedlot and carcass performance or from special feeder cattle marketing programs, emphasis on Feeder Advantage will enhanced post-weaning and carcass profitability.

LIMITATIONS TO USE OF GENEMAX ADVANTAGE

GeneMax Advantage is a collaborative effort between Zoetis, AGI and CAB designed for use in high-percentage Angus commercial replacement females. As a general rule, this means progeny of HD 50K and i50K-tested, registered Angus bulls mated to half-blood or greater Angus cows (i.e., heifers that are 75% or greater Angus genetics). It is not intended for use in registered Angus females or bulls. The predictions obtained with GeneMax Advantage are not incorporated into the AGI's NCE and do not influence the GE-EPDs of registered animals.

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