How many progeny are needed for on-farm evaluation of breeding merit of Wagyu cattle?

Before genomic EBVs became available, I used to suggest that some progeny should be raised for carcass analysis when potential young sires needed to be evaluated for breeding merit. However, I started to get some doubts when I detected that the association between predicted breeding values and progeny test results in Japan was quite low during the period when Yasufuku and his contemporaries were going through progeny testing.

The difficulty in determining sire effects from raw data from progeny test results is illustrated by the example of two sires from the generation following after Yasufuku that had their progeny scored under the same JMGA standards. The average from the progeny tests for Tanifuku Doi (with blue bars in the chart below) was 3.2 and the average for Yasuku 6-3 (with red bars) was 28% lower with an average score of 2.3 (小野健一 続・日本名牛百選).

The distribution of BMS is illustrated below. 87.5% of Tanifuku Doi’s progeny scored 3 or higher, whilst 60% of Yasuku 6-3’s progeny scored 2+ or lower. Both sires performed well in their progeny tests, but progeny from Tanifuku Doi had a higher average. However, when the final evaluation was completed using best linear unbiased prediction (BLUP), the order was different. BMS predicted breeding value for Yasuku 6-3 was 1.445 with an accuracy of 0.948 and this ranked him 13th in Hyogō in July 2001. Tanifuku Doi was posted with 1.350 with an accuracy of 0.920 in March 2002 and he was ranked 20th. Even though the difference was only a 7% advantage in BMS PBV for Yasuku 6-3 over Tanifuku Doi, it does correct the initial impression assessment that could have been made if only raw data from eight to 10 progeny in a controlled progeny test in Japan had been used. The environmental influences – such as genetic contribution and age of dam, etc - need to be eliminated from progeny test by BLUP analysis.

This prompts the question “how many progeny are actually needed to reveal breeding merit on-farm if ten is insufficient?”

The accuracy from progeny tests in Japan, Australia and USA are reviewed to enable recommendations to be made for on-farm evaluation.
BMS and Progeny testing in Japan

Within another ten years of testing an average of ten progeny per sire, the number of progeny from each each sire was doubled. The raw data from 20 progeny from the prefectural stations were reviewed (小野健一 新・日本名牛百選, 小野健一 日本名牛百選IV and 小野健一 日本名牛百選v). The association between BMS breeding value with BMS average from progeny test from 10 Fullblood (100% pure Wagyu) progeny per sire was positive but weak ($r = +0.17$). The association increased by more than double from an average of 20 progeny per sire ($r = +0.39$) but even that would not be considered to give enough confidence to make selection decisions. It was much later that digital imaging exposed the variation of IMF% within each BMS grade. The measurement of marbling using BMS is not precise so the number of results that are required to be to predict marbling breeding value needs to be high. Measuring Rib Eye Area and Carcass Weight is more accurate than measuring Marbling % and there is a higher correlation between predicted breeding value (PBV) and progeny test results for those traits. A lower number of progeny would be required to obtain an indication of breeding merit for Rib Eye Area and Carcass Weight than the number that is required to evaluate Marbling.

The overlap in IMF% between each BMS for Fullblood and F1 Wagyu is illustrated below, to the left (Kuchida K, undated). The lowest reading for BMS 8 was 44% IMF, and the highest for BMS 8 was 67%. The highest IMF% did not fluctuate much between BMS 8 through to BMS 12.

It is challenging to manually interpret the raw data from a field progeny test using 20 progeny from each sire. BMS progeny tests from two modern Japanese Black sires processed by Iwate Prefectural Research Centre are presented in a chart above, and to the right hand side. The average BMS for the sire with black bars is 8.76 and the average for the sire with blue bars is slightly lower with an average BMS of 8.50. The difference is only 3% so both sires could be expected to have similar breeding values from the averages.

The published BMS predicted breeding value in Iwate prefecture for 菊福秀 in black bars is 49% higher than that for 金菊徳 with blue bars. A simple average from the tests rates them to be almost equal but it required a BLUP analysis to establish breeding merit which gives the blue bar bull almost a 50% higher predicted breeding value. This demonstrates that 1, 5, 10 or even 20 progeny - as in this example - may not be sufficient to truly reveal Wagyu
marbling breeding merit when only progeny test BMS results are used without a BLUP analysis.

**Australian BLUP and grading**

In Australia, AUS-MEAT and MSA marbling reference standards are assessed visually. The AUS-MEAT marble score is the grade that is more commonly referred to. Variation in IMF% within each Marble Score grade is extensive and there is considerable overlapping between different Marble Scores (Grose J, 2011).

Despite a strong correlation of marbling (IMF) % with the AUS-MEAT Marble Score ($r = 0.88$), the inconsistency in the grading of marbling in Australia appears to be a major factor that resulted in a low heritability of marbling in Wagyu of 0.23 when measurement was by AUS-MEAT Marble Score (Maeda et al 2013). Heritability increased to 0.54 when IMF% was used from digital imagining for the measurement of marbling. The implications from this are that a higher number of progeny are required from AUS-MEAT Marble Score grading than when digital imaging is used to obtain the equivalent accuracy of marbling merit in Wagyu in Australia.

Progeny data from Sher Wagyu sires were presented during the Australian Wagyu Association tour to Sher Wagyu in May 2019. A strong association was observed by Wagyu International when the kill sheet data for AUS-MEAT Marble Score was compared with genomic Marble Score EBVs in Australian BREEDPLAN. The chart is displayed below, to the left. The average Marble Score for progeny ranged from 7.1 to 9.7 and the range in MS EBV was from +0.5 to +1.4.
The accuracy for genomic Marble Score EBV was strongly associated with the number of Carcass Progeny for the sires bred by Sher Wagyu. The relationship is illustrated in the chart on the previous page, to the right. Accuracy was 65 and 66% for genomically enhanced EBVs without and progeny, and increased to 68% for 1 Carcass Progeny, to 71% for 2 Carcass progeny, and through to 84% from 38 Carcass progeny. One sire is the outlier in both charts. This is Murai who has a mid-parent MS prediction of +0.4 but the genomic EBV is +1.3. The average grade for his progeny is MS 8.2 and this score cuts the trend line in the chart at an MS EBV of +1.0. Despite data from 7 Carcass Progeny, the accuracy for Marble Score gEBV is 66%. MS accuracy is 68% for 1, and 71% for 2 Carcass Progeny. The low accuracy from single step gBLUP is flagging that there is low confidence in this EBV from the data that has been submitted from the progeny and DNA relatives. This is the only anomaly in this group because the other sires do not deviate very far from the trend lines in both charts.

Nearly 1,500 progeny from 30 sires were finished at Mayura Station. In my analysis of the data posted by Lamb (2019), the association between AUS-MEAT Marble Score average per sire with Marble Score EBV of each sire was stronger when there were more than 50 carcasses per sire. It became weaker with fewer carcasses and many some associations were strong and close to the trend line but divergence from the trend line was greatest for fewer than 10 carcasses per sire.

It is concluded by Wagyu International that fewer than 50 carcass progeny are not a reliable indication of breeding merit for marbling when they are graded by AUS-MEAT Marble Score. Scott is reported in the same article to say that a minimum of 50 Fullblood carcasses from A.I. sires are required for any kind of reliability. We are both in agreement. However, he does lower the threshold to 10 carcasses for natural service sires, and 2 for dams because there just are not enough from those parents otherwise. Scott uses EBVs in combination with performance data and twice I have heard him say that the value per carcass has gained by $500 through his use of Eye Muscle Area EBVs from BREEDPLAN in his breeding program.

The accuracy for MS gEBV of the 2018 calf crop at Mayura Station has been found by Wagyu International in a dump from the Australian Wagyu association database to average 60.9%, with a range extending from 52 to 65%. As yearlings, there are no Carcass Progeny yet from this mob.

Lone Mountain Ranch in USA has been using digital imaging for a number of years and sending the output to Australian BREEDPLAN. This has resulted in much of the herd having either genomic EBVs, or EBVs from carcass progeny alone, or both. The relationship between the number of carcass progeny and the correlation between IMF% and AUS-MEAT Marble Score EBV was reviewed from data posted by Lamb, 2018.

Once again, the outliers in chart above catch the eye. The two sires with the highest average IMF% content have only had four and six carcasses analysed each. They are represented by the two blue dots to the very right in the chart on the next page, while their EBVs are +1.6 and +1.7, but they do not have the highest MS EBVs. The averages from this cluster with a limited number of progeny show the greatest deviation from the trend of correlation of IMF% with breeding value for this herd. There is a stronger association between IMF% from
progeny with sire AUS-MEAT Marble Score EBV when there are at least ten carcass progeny with digital imaging per sire.

The accuracy from breeding values increased in Australia from the implementation of single step technology together with genomically enhanced evaluations. A review from a dump of estimated breeding values from the AWA database from animals which do not have carcass progeny showed a trend of an increase overall of about 5% when genomic EBVs from DNA are compared with the conventional EBVs that were based on pedigree relationships. The trend is illustrated in the chart below. Two-thirds of MS gEBVs had accuracies of 60% or higher.

When data from carcass progeny are added to gEBVs, there was a marked increase in accuracies. 10 carcass progeny increased accuracy from 60% to around 75% in this random pool, but there is quite a variation because a number of different factors contribute to accuracy. The accuracy from approximately 50 carcass progeny was 85%. When the number of carcass progeny increases above 150, the influence on accuracy of genomic EBVs does not appear to increase proportionally above 95% and has very little effect in differentiating breeding value.

New registrations in Australia are mainly processed by using the 50K SNP profile so genomic EBVs are rapidly becoming the standard in that population. Most of the foundation sires
were profiled by HD SNP in a process that commenced many years ago when the reference for the Wagyu breed was being built up.

Genomic EBVs in Australian BREEDPLAN are an excellent starting point, but the accuracies must be checked in every case. The average for the original Foundation Marble Score EBV sires is +0.3. The average Marble score EBV for the 2017 born calf crop at +0.6 is virtually double that. The increase in breeding merit of the younger generation of Wagyu over that from the original founders is confirmation of progress with breeding merit since the introduction of carcass EBVs. The pace of improvement is more likely to increase because the generation interval for selection will be reduced because initial assessment is carried out at a younger age when a hair sample can be taken. The long generation interval in cattle hinders the rate of genetic improvement when compared to most other farm species.

**USA progeny testing.**

HeartBrand publishes expected progeny differences (EPDs) for Red Wagyu/Akaushi in their semen sale catalogues and some are displayed on the Wagyu Sekei directory. Predictions from the most popular sires were extracted from the 2018 Directory. Accuracies of EPDs were highest for Birth Weight and Weaning Weight with averages above 60% and they exceeded an average accuracy of 40% for Maternal Milk and 12th Rib Fat Thickness. Accuracy was lowest for Intramuscular with a range from 1 to 28%, and an average accuracy of 7%. Highest correlations between Heartbrand EPDs and BREEDPLAN EBVs were highest for Milk, then Weaning weight, then finally for Backfat and Yearling Weight. Correlations were weak or negative for Ribeye Area, Intramuscular Fat and Birth Weight.

<table>
<thead>
<tr>
<th>HeartBrand traits</th>
<th>Birth Weight</th>
<th>Weaning Weight</th>
<th>Yearling Weight</th>
<th>Maternal Milk</th>
<th>Intramuscular Fat</th>
<th>Ribeye Area</th>
<th>12th Rib Fat Thick</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum accuracy EPD</td>
<td>37%</td>
<td>31%</td>
<td>6%</td>
<td>16%</td>
<td>1%</td>
<td>5%</td>
<td>9%</td>
</tr>
<tr>
<td>Maximum accuracy EPD</td>
<td>95%</td>
<td>92%</td>
<td>53%</td>
<td>87%</td>
<td>28%</td>
<td>53%</td>
<td>80%</td>
</tr>
<tr>
<td>Average accuracy EPD</td>
<td>73%</td>
<td>63%</td>
<td>25%</td>
<td>47%</td>
<td>7%</td>
<td>27%</td>
<td>42%</td>
</tr>
<tr>
<td>Correlation HB EPD BP EBV</td>
<td>+0.23</td>
<td>+0.53</td>
<td>+0.46</td>
<td>+0.71</td>
<td>-0.15</td>
<td>-0.34</td>
<td>+0.46</td>
</tr>
</tbody>
</table>

The low accuracies and low correlations between HeartBrand EPDs with corresponding BREEDPLAN EBVs suggest that the measurement of Intramuscular Fat and Ribeye Area may not be accurate in USA. Genetic progress will be hindered if phenotypic measurement is not concise or if cohorts with common links are not processed together in each batch.

The highest beef quality from USDA grading is Prime which has a minimum IMF requirement between 8 and 11%. USDA Prime is equivalent to AUS-MEAT Marble Score 5 which is average for F1 in Australia and virtually top of the range for Angus.

The American Wagyu Association publishes EPDs that have been generated from F1 progeny by Washington State University to give the best estimate of Black Wagyu sires’ genetic potential in USA. An association was found by Wagyu International between 2017 Marbling EPD’s with AUS-MEAT Marble Score EBVs (R = + 0.57) from Australian BREEDPLAN. The correlation was + 0.68 for sires that had accuracies above 0.4 for marbling EPD, but it dropped to + 0.44 for those that had accuracy that was below 0.4. This suggests that performance from sires that have an EPDs with accuracy that is lower than 0.4 may not be
consistent over time. 70% of the sires that have reported Marbling EPDs in the 2017 National Wagyu Sire Summary have an accuracy that is below 0.4.

There is a strong association of number of progeny per sire with the accuracy of marbling EPD (R = + 0.63) and individual charts illustrate the relationship for Marbling, Rib Eye Area, Carcass Weight and Subcutaneous Fat Thickness ‘backfat’ EPDs.

The average number of progeny that are expected to give accuracy of 0.4 for Marbling EPD is almost 25 and this is the number of F1 progeny that would be expected on average to give accuracy that exceeds 0.4 by evaluation from BLUP/Bolt analysis.
The correlation between Eye muscle (Rib eye) area EBV from Australian BREEDPLAN and EPD from Washington State is higher for accuracies greater than 40% (R = + 0.77) than when accuracy was lower than 40% (R = +0.63). Fewer progeny are required to obtain the same accuracy with Rib eye area EPD in USA than from Marbling EPD.

It is summarised that 25 F1 progeny, after analysis by BLUP/Bolt, will give an accuracy of 0.4 for marbling. A review of the chart showing accuracy of Marbling EPD suggests that more than 150 F1 progeny would be required to give Marbling EPD accuracy of 0.6 after analysis by BLUP/Bolt. The trend line cuts the 0.75 accuracy line at 650 F1 progeny.

60% accuracy is the baseline from Marble Score genomic EBVs in BREEDPLAN. Five sires have Marbling EPD accuracy of 0.6 or higher. There is one with Rib Eye Area EPD accuracy above 0.60 but there are none with External Fat EPDs that equal or exceed 0.6. There are 29 with Hot Carcass Weight EPDs with an accuracy of 0.6 or higher. Amongst these, the sire with highest Marbling EPD is Sanjirou with +0.48 and second highest is Michifuku with +0.42.

Semen from twelve World K’s sires generated 36,000 F1 progeny that were finished for 540 days (Wallace, B, 2009 and World K’s website 2011). Daily gain over 540 days was averaged from progeny from each sire and grades were recorded as percentage within 1-3, 4-6, 7-9 and 9+ AUS-MEAT Marble Score. Weighted average Daily Gain was 1.0 and 80% of the progeny graded 9+, 18% were between MS 7 and 9, and 2% were between MS 4 and 6. Average number of F1 progeny from each sire was three thousand but there were only 200 progeny from Yasufuku 5, and 350 from Michitsuru; but as many as 12,000 from Michifuku.

Data from sires with low numbers of progeny and from low accuracy EBV sires were excluded from the analysis of correlations between estimated AUS-MEAT Marble Score estimated breeding values of the sires with the Marble Score grades from their progeny. The association was positive (r = + 0.30) between gEBV and the percentage that graded 9+ but the association was stronger (r = + 0.56) between gEBV and average Marble Score when the full spectrum of progeny were included. The MS gEBVs for the World K’s sires ranged from
– 0.4 to + 2.0. Between 65 and 90% of the progeny graded 9+. The association for marbling is charted below, to the left:

There are some outliers that are distant from the trend line, but the positive association confirms that F1 progeny can be used to endorse marbling breeding value of sires. In this situation, the average number of progeny per sire was higher than 3,000; and sires with fewer than 800 progeny were excluded because there was no BLUP analysis. Another contributing factor would be the long period of finishing of 540 days because it is common to feed F1 commercially for between 350 to 400 days.

Daily gain of progeny during finishing was tested for an association with 200 Day, 400 Day, 400 Day, Mature Cow Weight and Carcass Weight EBVs of the sires. The data is charted above and to the right. Strongest association of Daily Gain from finishing F1 progeny over 540 days was with Carcass Weight and 400 Day Weight EBVs ($r = +0.74$), then 200 Day Weight ($r = +0.71$) and finally 600 Day Weight ($r = +0.68$). Highest bodyweight gain usually occurs during early finishing so this could trigger the marginally stronger association of daily gain with 400 day EBV than with 200 or 600 day EBV.

Delegates to the Australian Wagyu Association tour to Nick & Vicky Sher’s property in Victoria in May 2019 were told that they evaluate their candidate sires on-farm by using F1 progeny. While walking through the paddocks I asked Leigh Bradbury, Operations Manager, how many progeny results are required from each sire for on-farm breeding evaluation. He answered 70. At the time I thought that this number was high, but when this is related to the USA results, 70 F1 progeny there give approximately 50% accuracy from BLUP evaluation. However at the Sher property, cohorts could be raised in large herds, and there should be more consistency within one operation than over the potential diversity in a different of different herds in the Washington State pool.

**On-farm evaluation of progeny test results**

In each instance that has been reviewed above, it has been demonstrated in Japan, USA and Australia that large numbers of either Fullblood or F1 progeny are required to ‘prove’ the breeding merit of a Wagyu sire or dam. This can be fast tracked by securing genomic EBVs at a young age. Breeding merit is locked in at conception and as soon as a hair sample can be taken, genomic EBVs can be obtained which give an average accuracy of 60% for marbling. This is usually carried out when registration is undertaken of weaners together with DNA parent verification. The first phenotypic examination can be carried out on-farm when genomic EBV results are posted after parent verification completes the registration process.
Selection is completed using weaning performance, conformation and genomic EBVs. Carcass traits with economic importance are given higher priority for use in production; or maternal traits are weighed up with pedigree, prefectural classification and conformation for seed stock breeding. Either way, the best young bulls and heifers are retained for breeding or sale while the remainder are processed. Semen is taken from the very best elite bulls so that ten carcass progeny can be produced from each within about four years to prove the very best candidate sires. If insufficient accuracy has been generated for any sires from ten carcass progeny, then it may possibly not be worth persevering with them. Low accuracies flag that inconsistent associations have been encountered in the data. Causes can range from low genetic merit from the candidate, insufficient cohorts or links, etc.

Commentary that I read on social media in USA says “While genomics can be a valuable tool to assess what genes, traits, strengths, or weaknesses animals inherited from each parent, it is not an absolute measure of potential or a guarantee of performance. Remember, genomics in Wagyu still have relatively low reliabilities and are only as good as the data that was originally input into the system (Lamb 2019).” These comments apply equally to the importance of accuracy of EPDs from HeartBrand and Washington State in USA as they are to the accuracies of genomic EBVs in Australia. I believe that reliability generally improves from an accuracy of about 60% (or 0.6 in USA terminology).

What should the benchmark be? Through the media there are frequent claims of superior breeding prowess that are based on results from a low number of progeny. To keep this in perspective, it should be remembered that Scott de Bruin requires 50 Fullblood progeny for reliability, and Sher Wagyu screen with 70 F1 progeny. I asked a Japanese scientist this week what he thought the value from 20 Fullblood progeny was. “Useless” was the reply.

The target is 75% accuracy, and this will be secured in most cases from:
10 carcass progeny in combination with genomic EBVs.
Alternatively, BLUP/Bolt analysis from 650 F1 progeny will give the same result.

60% accuracy should be obtained from:
Genomic EBVs, or
BLUP analysis from 20 Fullblood progeny, or
40 Fullblood progeny, or
BLUP/Bolt analysis from 150 F1 progeny.

So what is the lowest number of progeny per parent for any credible claims to be made? Results from fewer progeny than 20 Fullblood or 70 F1 should be considered to be speculative.

It is just a fact of life that the 50% contribution of DNA from the dam in every union requires a large number of offspring to give an indication of a sire’s breeding merit. Sadly it turned out to be many more than I originally expected.
Definitions

Refer to Definitions at the end of "Factors influencing, and selection for, eating quality in Wagyu beef".

Steve Bennett

Wagyu International

4th November 2019

Check this webpage for any updates that have been posted to this report: “How many progeny are needed for on-farm evaluation of breeding merit of Wagyu cattle?”

References and further reading


HeartBrand 2018 Sire Directory. Internet.


Lamb, Mitchell & Lindsay, 2018. Lone Mountain Ranch. International Wagyu Breeder e-magazine, July/August 2018:12


小野健一 日本名牛百選
小野健一 続・日本名牛百選
小野健一 新・日本名牛百選
小野健一 日本名牛百選Ⅳ
小野健一 日本名牛百選V

Sher, Nick, 2019. Data from presentation on Australian Wagyu Association tour to Sher Wagyu. 12th May 2019.


World K’s website.