Optimizing age at first use of semen for higher fertility in Sahiwal breeding bulls

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ABSTRACT
The objective of the study was to optimise the age at first use (AAFU) of semen in Sahiwal breeding bulls which will help in early selection of bulls under progeny testing programme. The data on AAFU, conception rate based on first A.I. (CRFAI), overall conception rate (OCR) and birth weight (B.WT) of 43 Sahiwal bulls during 1987 to 2013 at NDRI centre pertaining to 8 sets of Sahiwal improvement programme at ICAR-NDRI, Karnal, India were adjusted for significant environmental influences and subsequently analyzed. Simple and multiple regression models were used for prediction of CRFAI and OCR of Sahiwal bulls. Comparative evaluation of three developed models (I to III) have showed that Model III, having AAFU and B.WT which fulfill the accuracy of model as revealed by high coefficient of determination, low mean sum of square to due error, low conceptual predictive value and low Bayesian information criterion. The results showed that average predicted CRFAI was highest (49.34%) at <5 years and lowest (44.79%) at >6 years of age at first A.I. /use. Similarly average predicted OCR was highest (48.50%) at <5 years and lowest (44.56%) at >6 years of age at first A.I. /use of Sahiwal bulls. In organized herd under progeny testing programme, Sahiwal bulls should be used prior to 5 years which is expected to result in 4.45% better CRFAI and 3.94% better OCR in comparison to Sahiwal bulls used after 6 years of age.

Key words: Birth weight, Bull’s age, Conception rate, First semen use, Sahiwal bull.

INTRODUCTION
Sahiwal is one of the best dairy cattle breed of South-Asia which is having superior genetic potential for milk production. Sahiwal breeds were imported by other countries (like Brazil, Australia, West Indies and Bangladesh etc.), mainly for introducing some common genes in crossbred animals for developing synthetic strains worldwide. It has been reported that the indigenous cows are less susceptible to reproductive problems than crossbred cows (Bitew and Prasad, 2011). However, more than 52 per cent indigenous cows inducted for semen collection programme had problems with semen quality and libido (Mandal and Tyagi, 2004).

Birth weight is one of the main economic traits for the subsequent growth rate and milk production. The birth weight of Sahiwal bull cows can be used as one of the selection criteria at an early age. The demand for the best bulls has increased considerably as bull plays an important role in a successful reproductive management programme (Chenoweth and Lorton, 2014). The primary goal of any A.I. organization is to produce the largest quantity of the highest quality semen in a shortest possible time. Timed A.I. programmes provide an organized approach to enhance the use of A.I and to improve reproductive efficiency in cattle.

Actual fertility levels are the result of a combination of genetic potential and environmental factors including nutrition, health, and cow and bull care and management (Hamilton, 2009).

The total genetic gain obtained through sire to sire path and sire to dam path is about 64 per cent, results in greater accuracy for estimating the breeding value of sires and the production of a larger number of daughters which make contributions as replacement stock for the next generation. Therefore, the importance of genetically superior bull as a producer of large quantities of normal fertile spermatozoa in any programme of artificial breeding/ insemination is obvious and obtaining semen at the earliest possible age from bulls is not only economical but also may increase productive life span and genetic testing of bulls at an early age (Dahiya and Singh, 2013). Indiscriminate use of breeding bulls without proper evaluation poses a potential threat to the dairy industry as it may transmit undesirable traits besides contributing to poor fertility of the herd. It has been found that sire age affects conception rate (CR) in dairy cattle (Kuhn et al., 2006). Age of the bull at the time of mating is the major factor to determine reproductive performance of bulls (Kuhn and Hutchison, 2008). A bull’s highest fertility is at 2-4 years of age, on an average and

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after four years of age there may be some decline in fertility, but this is not very noticeable until a bull gets to be 5-6 years of age (Thomas, 2009). Optimizing the age at first use of semen in relation to fertility will help in selection and use of breeding bulls at right age thereby improving the herd efficiency. Keeping the above aspects in view, an attempt was made to optimise the age at first use of Sahiwal bulls, which would facilitate selection of the bulls at the right age and designing effective breeding programme.

MATERIALS AND METHODS

Livestock farm: The study was conducted on the records of 43 Sahiwal bulls maintained under 8 sets of Sahiwal improvement programme at Artificial Breeding Complex, National Dairy Research Institute (NDRI), Karnal, Haryana, India. Farm is situated at an altitude of 235 to 252 meters (748 feet) above the mean sea level at 29.68°N latitude and 76.98°E longitude in eastern zone of Haryana which comes under the Trans-Gangetic plain agro climatic zone of India. The climate that prevails is subtropical and the temperature in summer months (April to June) ranges between 24°C-44°C. Karnal experiences moderate rainfall in the months of July which lasts till September. Winters are extremely cold and the temperature ranges from 4°C to 32°C in winter months. Each year was sub-classified into four major seasons viz., winter (December to March), summer (April to June), rainy (July to September) and autumn (October to November), based on date CSSRI, Karnal (Singh, 1983).

Traits: The traits under study were age of bulls at first use (AAFU), conception rate based on first A.I. (CRFAI), overall conception rate (OCR) and birth weight (B.WT) of Sahiwal breeding bulls. On standardization and normalization of traits, the number of bulls remained in the analysis were 40 for age at first use and 43 for conception rate based on first A.I., overall conception rate and birth weight.

Statistical analysis: To analyse the effect of non-genetic factors, the data were classified into different sub-classes as period of A.I., season of A.I., parity of dam, stages of lactation and age of cow. To study the influence of various non-genetic factors, the data were classified into various sub-classes as season of birth, period of birth, parity of dam and age of dam for birth weight trait (B.WT). All traits of Sahiwal bulls were adjusted for significant non-genetic factors by using fixed linear models. Since the data were non-orthogonal, the least-squares technique suggested by Harvey (1990) was used to estimate the effect of non-genetic factors on various traits of Sahiwal breeding bulls. Thereafter, Duncan’s multiple range test, as modified by Kramer (1957), was used for testing the differences among least-squares means.

The model for age at first use was considered as,

\[ Y_{ijklmn} = \mu + P_i + S_j + P_Ak + S_L + b(AF_m - A\bar{F}) + e_{ijklmn} \]

where,

- \( Y_{ijklmn} \) = Observation on the \( n^{th} \) bull in \( i^{th} \) period of A.I., \( j^{th} \) season of A.I., \( k^{th} \) parity of cow, \( l^{th} \) stages of lactation of cow and \( m^{th} \) age of cow
- \( m \) = Overall mean
- \( P_i \) = Effect of \( i^{th} \) period of A.I. (1 to 8)
- \( S_j \) = Effect of \( j^{th} \) season of A.I. (1 to 4)
- \( P_Ak \) = Effect of \( k^{th} \) parity of cow (1 to 5)
- \( S_L \) = Effect of \( l^{th} \) stage of lactation of cow (1 to 3)
- \( b \) = Regression of age of cow on AAFU
- \( AF_m \) = Age of \( m^{th} \) cow
- \( A^F \) = Average age of cow
- \( e_{ijklmn} \) = Random error ~ NID (0, \( \sigma^2_e \))

The model considered for conception rate based on first A.I. and overall conception rate of Sahiwal bulls was considered as,

\[ Y_{ijklmn} = \mu + P_i + S_j + P_Ak + S_L + b(AF_m - A\bar{F}) + e_{ijklmn} \]

where,

- \( Y_{ijklmn} \) = Observation on the \( n^{th} \) bull in \( i^{th} \) period of A.I., \( j^{th} \) season of A.I., \( k^{th} \) parity of cow, \( l^{th} \) stages of lactation of cow and \( m^{th} \) age of cow
- \( m \) = Overall mean
- \( P_i \) = Effect of \( i^{th} \) period of A.I. (1 to 8)
- \( S_j \) = Effect of \( j^{th} \) season of A.I. (1 to 4)
- \( P_Ak \) = Effect of \( k^{th} \) parity of cow (1 to 5)
- \( S_L \) = Effect of \( l^{th} \) stage of lactation of cow (1 to 3)
- \( b \) = Regression of age of female on the CRFAI and OCR
- \( AF_m \) = Age of \( m^{th} \) cow
- \( A^F \) = Average age of cow
- \( e_{ijklmn} \) = Random error ~ NID (0, \( \sigma^2_e \))

The model considered for birth weight of Sahiwal bulls was considered as,

\[ Y_{ijklmn} = \mu + P_i + S_j + P_Ak + b(AD_m - A\bar{D}) + e_{ijklmn} \]

where,

- \( Y_{ijklmn} \) = Observation on the \( n^{th} \) bull in \( i^{th} \) period of birth, \( j^{th} \) season of birth, \( k^{th} \) parity of dam and \( m^{th} \) age of dam
- \( m \) = Overall mean
- \( P_i \) = Effect of \( i^{th} \) period of birth (1 to 8)
- \( S_j \) = Effect of \( j^{th} \) season of birth (1 to 4)
- \( P_Ak \) = Effect of \( k^{th} \) parity of dam (1 to 5)
- \( b \) = Regression of age of dam on birth weight of bulls
- \( AD_m \) = Age of \( m^{th} \) dam
- \( A^D \) = Average age of dams
- \( e_{ijklmn} \) = Random error ~ NID (0, \( \sigma^2_e \))

Model used for prediction of conception rate in Sahiwal bulls: Simple and multiple regression analysis were performed for prediction of conception rate (first A.I. and overall) using the SAS Systems programs (SAS 9.4V, SAS Institute Inc., Cary, NC, USA). Three models were developed by using all possible combination of age at first use and birth weight for prediction of conception rate. The coefficient of determination (\( R^2 \)) for each model is estimated and expressed in terms of percentage. Mallow’s conceptual predictive value is used for predicted model selection (Mallows, 1973). Akaike information criterion (AIC) as developed by Akaike (1974) and Bayesian information
criterion (BIC) as developed by Schwarz (1978) was also estimated for model selection with different numbers of parameters. The model with lowest AIC value, BIC value, CP = <P, high R² and minimum mean sum of squares due to error using combination of age at first use and birth weight were judged as optimum model for prediction of CRFAI and OCR in Sahiwal bulls.

**Optimisation of age at first use:** Three age groups of bulls were considered viz; <5 years, 5-6 years and >6 years. The highest conception rate (first A.I. and overall) corresponding to the lowest age at first use of bulls was optimised by judging the predicted conception rates and average error of prediction in the respective age groups.

**RESULTS AND DISCUSSION**

The main objective of this study is to reveal the optimizing age at first use in relation to fertility of Sahiwal breeding bulls which will help for improving the reproductive performance in the herd. Age at first use indicates the age of bulls when the semen is used first in the herd for improvement of Sahiwal breeds. Under the Sahiwal improvement programme, bulls are mainly selected based on the daughter’s performance. Minimum 6 to10 bulls in each set are used in Sahiwal improvement programme and the set duration of each set (test cycle) is around 24 months. But set duration of Sahiwal bulls may vary from one set to another set due to less numbers of progeny in that particular time. In this study, 8 sets of Sahiwal bulls were used at NDRI herd, evaluated with minimum number of three bulls in III and IV set and maximum number of eight bulls in X set from NDRI herd.

**Effect of non-genetics factors on age at first use, conception rate based on first A.I., overall conception rate and birth weight of Sahiwal bulls:** AAFU of semen were influenced by period of A.I. (P < 0.01) and CRFAI and OCR of Sahiwal bulls were also found influenced by period of A.I. (P < 0.01) as presented in Table 1. Birth weight of Sahiwal bulls was influenced by period of birth (P < 0.01) in this study. The effect of season, parity, stage of lactation and age of cow were found non-significant on all of the traits. Least-squares means of AAFU, CRFAI, OCR and B.WT were estimated as 5.25 ± 0.02 years, 46.24±0.35 %, 46.86±0.27 % and, 22.04±1.08 kg, respectively.

**Optimizing age of bull at first use of semen in relation to conception rate:** The models applied for prediction of conception rate based on first A.I. and overall conception rate of Sahiwal bulls have been developed using simple and multiple regression analysis. The intercept and regression coefficient of each model are presented in Table 2. For judging the optimum model for conception rate based on first A.I. and overall conception rate of Sahiwal bulls various criterion values like R², MSSE, CP, AIC and BIC values for each model were estimated and shown in Table 3. Looking into the judging of models, it was observed that the Model III having birth weight and age at first use fulfilled four criterions like high R², low MSSE, low CP and low BIC value.

For optimizing age at first use in relation to fertility (conception rate based on first A.I.) of Sahiwal bulls, age at first use was classified into three groups i.e. <5 years, 5-6 years and >6 years and average predicted conception rate in three age groups with the corresponding average birth weight of bulls are presented in Table 4. In similar fashion, for optimizing age at first use in relation to fertility (overall conception rate based on first A.I. and overall conception rate) the models were applied. The models were considered as optimum models if the models having highest R², lowest MSSe, lowest CP and lowest BIC values were considered as optimum models.

**Table 1:** Analysis of variance (M.S. values) of birth weight, age at first use (AAFU), conception rate based on first A.I. (CRFAI) and overall conception rate (OCR) of Sahiwal bulls

<table>
<thead>
<tr>
<th>Sources of variation</th>
<th>Birth Weight (kg)</th>
<th>AAFU (yrs)</th>
<th>CRFAI (%)</th>
<th>OCR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period of birth/use/A.I.</td>
<td>9.46** (7)</td>
<td>203.27***(6)</td>
<td>836.90** (7)</td>
<td>1332.27***(7)</td>
</tr>
<tr>
<td>Season of birth/use/A.I.</td>
<td>22.26 (3)</td>
<td>0.31 (3)</td>
<td>282.84 (3)</td>
<td>175.00 (3)</td>
</tr>
<tr>
<td>Parity</td>
<td>10.85 (4)</td>
<td>0.26 (4)</td>
<td>111.60 (4)</td>
<td>68.44 (4)</td>
</tr>
<tr>
<td>Stage of lactation</td>
<td>-</td>
<td>1.77 (2)</td>
<td>15.83 (2)</td>
<td>34.46 (2)</td>
</tr>
<tr>
<td>Age of cow</td>
<td>7.43 (1)</td>
<td>0.14 (1)</td>
<td>0.065 (1)</td>
<td>25.30 (1)</td>
</tr>
<tr>
<td>Error</td>
<td>7.59 (27)</td>
<td>0.64(2459)</td>
<td>86.34 (1958)</td>
<td>73.92 (2557)</td>
</tr>
</tbody>
</table>

Figures in parentheses indicate respective degrees of freedom. **P < 0.01

**Table 2:** Estimation of intercept and regression coefficients for prediction of conception rate based on first A.I. and overall conception rate for Sahiwal bulls

<table>
<thead>
<tr>
<th>Traits</th>
<th>Conception rate based on First A.I.</th>
<th>Overall conception rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intercept</td>
<td>Regression coefficients</td>
</tr>
<tr>
<td></td>
<td>b₁</td>
<td>b₂</td>
</tr>
<tr>
<td>AAFU</td>
<td>24.59</td>
<td>3.97</td>
</tr>
<tr>
<td>B.WT</td>
<td>1.39</td>
<td>2.02</td>
</tr>
<tr>
<td>AAFU,B.WT</td>
<td>-32.85</td>
<td>-32.85</td>
</tr>
</tbody>
</table>

AAFU= age at first use; B.WT=birth weight
Table 3: Estimation of criterion values, for judging optimum model for conception rate based on first A.I. and for overall conception rate in Sahiwal bulls

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Traits</th>
<th>P</th>
<th>R²</th>
<th>MSSe</th>
<th>Cp</th>
<th>AIC</th>
<th>BIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>AAFU</td>
<td>2</td>
<td>0.320</td>
<td>0.1873</td>
<td>2.00</td>
<td>-38.13</td>
<td>-5.84</td>
</tr>
<tr>
<td>II</td>
<td>B.WT</td>
<td>2</td>
<td>0.3798</td>
<td>0.1652</td>
<td>2.00</td>
<td>-49.38</td>
<td>-8.62</td>
</tr>
<tr>
<td>III</td>
<td>AAFU, B.WT</td>
<td>3</td>
<td>0.6135</td>
<td>0.1471</td>
<td>3.00</td>
<td>-57.24</td>
<td>-9.81</td>
</tr>
</tbody>
</table>

Overall conception rate

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Traits</th>
<th>P</th>
<th>R²</th>
<th>MSSe</th>
<th>Cp</th>
<th>AIC</th>
<th>BIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>AAFU</td>
<td>2</td>
<td>0.3743</td>
<td>0.1614</td>
<td>2.00</td>
<td>-50.63</td>
<td>-10.93</td>
</tr>
<tr>
<td>II</td>
<td>B.WT</td>
<td>2</td>
<td>0.3865</td>
<td>0.1385</td>
<td>2.00</td>
<td>-59.92</td>
<td>-12.41</td>
</tr>
<tr>
<td>III</td>
<td>AAFU, B.WT</td>
<td>3</td>
<td>0.6714</td>
<td>0.1117</td>
<td>3.00</td>
<td>-75.05</td>
<td>-14.76</td>
</tr>
</tbody>
</table>

P = number of parameters, R²=coefficient of determination, MSSe = mean sum of square due to error, CP= conceptual predictive value, AIC= Akaike information criterion, BIC= Bayesian information criterion

Table 4: Optimum age at first use and predicted conception rate based on first and overall A.I. of Sahiwal bulls in relation to birth weight

<table>
<thead>
<tr>
<th>AAFU (years)</th>
<th>No.of bulls</th>
<th>B.WT(Kg)</th>
<th>CRFAI (%)</th>
<th>Average prediction error (%)</th>
<th>OCR (%)</th>
<th>Average prediction error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5</td>
<td>21</td>
<td>23.35</td>
<td>49.34</td>
<td>3.69</td>
<td>48.50</td>
<td>3.63</td>
</tr>
<tr>
<td>5- 6</td>
<td>12</td>
<td>22.62</td>
<td>48.85</td>
<td>4.94</td>
<td>47.31</td>
<td>4.01</td>
</tr>
<tr>
<td>&gt; 6</td>
<td>7</td>
<td>21.82</td>
<td>44.79</td>
<td>6.64</td>
<td>44.56</td>
<td>6.08</td>
</tr>
</tbody>
</table>

B.WT= birth weight, AAFU = age at first use, CRFAI = conception rate based on first A.I and OCR = overall conception rate

conception rate) of Sahiwal bulls, average predicted conception rate in three age groups with the corresponding average birth weight of bulls are presented in Table 4.

So far, research work has not been carried out on optimization of AAFU of Sahiwal bulls for higher fertility in the herd. Most of studies have been reported that probability of the bull having a suitable age influences the conception rate in the herd. In dairy cattle, peak A.I. bull conception rate has been reported (Tanabe and Salisbury, 1946) at two years of age, whereas peak fertility at somewhat older ages of 3 to 4 years was also reported (Bishop, 1970). Age of the bull at the time of mating was the major factor with the variation of fertility and conception rate was maximum at 5 years of age, and then decreased somewhat approximately up to age 9-10 years (Kuhn and Hutchison, 2008). Several older studies on bull’s age were reviewed by (Salisbury et al., 1978). Therefore, it is worthwhile to bear in mind that appropriate management of pre-pubertal Sahiwal bulls is of strong value; if bulls are to be prepared for breeding at right age.

It should be emphasized that “bull’s age” in this reported research refers to age of the bull when semen is used in herd. Likewise, bull’s age at insemination may have been five years but semen would have been donated when the bull was 2-3 years old, for example, may have been used in the insemination programme. In spite of this caveat, results for bull’s age in Table 4 are generally consistent with the previous research and clearly showed marked improvement in predictions when bull age at first use was used in the predictor for the improvement of Sahiwal breeds. Improved energy based nutrition and management could possibly lead to further reduction in age at first use and improvement in predictions of conception rate of Sahiwal bulls. However, further study will be necessary incorporating age of the bull at the time of collection, bull’s age at first time use in the herd along with seminal parameters for assessing improved conception rate in the herd.

CONCLUSION

The results showed a negative association of conception rate with age at first use of Sahiwal bulls. To get maximum conception rate of Sahiwal bulls, age of the bull at first A.I. should be <5 years under our management regime. Bull’s age at A.I. was found to be a useful variable for improving the accuracy of predictions of bull’s fertility in the herd. The outcome of the present study will help in the early use of bulls thereby resulting in higher genetic and economic returns in a herd.

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