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Development of Prediction Equations to Estimate Potential Fertility of Tropical Dairy Bulls: Obsevation in India

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Abstract

This study was conducted with the aim of developing prediction equations to estimate potential fertility of breeding bulls at an early age at Artificial Breeding Complex of the National Dairy Research Institute, Karnal, India in 2002. Data were collected on body size and testicular measurements from 12 Sahiwal and 28 Karanfries dairy bulls. Multiple regression equations were constructed to predict scrotal circumference (SC), paired testis volume (PTV), total testis weight (TTWT) and body weight (WT) from age, linear body size (chest girth and height) and testicular measurements. Results indicate that testis characteristics can be predicted from body size measurements of animals. Significant advantages of testicular measurements like SC, testis length (TL) and testis width (TW) were discovered to reasonably predict PTV and TTWT, which have direct relationship with the capacity to produce spermatozoa. SC was best predicted from heart girth (G), body weight from G and age of the animal, PTV from SC, TL and TTWT and TTWT from TL and TW. Multiple regression equations were constructed and best models were presented for each parameter. These models indicate the potential fertility of a bull, based on measurements of testis size, and this facilitate culling decisions at an early age before investing money, labor, time and space in rearing bulls.

Keywords: Bull selection, body size, testicular measurements, prediction equation

Introduction

The productive capacity and physical appearance of animal populations can be changed by selective breeding. Man improves his livestock by limiting the reproduction of inferior animals and by choosing superior animals for mating

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to produce the progeny which constitute the next generation (Banerjee, 2002). Selection for higher milk yield in indigenous cattle breeds through culling of inferior cows and selection of young bulls on dam's yield and body conformation is the origin of animal breeding (Falvey and Chantalakhana, 1999). Sire selection, on average, has a greater impact on the genetic improvement of a herd than most producers realize. Because the sire is more likely to produce a higher number of calves in his lifetime compared to a cow, and has the potential to contribute a larger portion of the genes to the herd.

The association between body measurements and testicular characteristics has long been used to predict the potential fertility performances of a bull. So it could be advantageous if such traits like testes weight and volume which have direct relationship with the capacity of that particular animal to produce spermatozoa are reasonably predicted from simple, easy and accurate live measurements of the animal. This paper presents the best selected prediction equations for estimating potential fertility tropical dairy bulls using the relation of body weight and testicular measurements of a bull.

Materials and Methods

Study area

The study was carried out at Artificial Breeding Complex, National Dairy Research Institute, Karnal, India in 2002. The farm is situated at an altitude of 250 m above sea level on 29.42° N latitude and 77.42°E longitudes. The climate of the farm is sub-tropical with atmospheric temperature varing from near freezing point (0 °C) in winter months to about 45°C in summer months. The average annual rainfall is approximately 760 mm to 960 mm which is received mostly during months of July to August. Relative humidity varies from as low as 41 % to as high as 85%.

Animals and Management

The Sahiwal, one of the best dairy breeds of Zebu cattle of Indian subcontinent, has its origin in Montgomery district of Pakistan and is distributed in farmers' herds in certain pockets of bordering districts of Punjab and Rajasthan in India. It is available at organized farms in North, North Western and Central India. The importance of this breed is evident from the fact that Sahiwal animals have been imported by countries, like Kenya, Tanzania, Australia, West Indies and Bangladesh. The breed has been imported by these countries either for crossbreeding with their local breeds or for incorporating some Zebu genes in crossbred animals for developing synthetic strains, like, Jamaica Hope, Australian milking zebu and Australian Friesian Sahiwal besides Mpwapwa and Pabna crosses. Karan Fries is a cross of Sahiwal and Holstein-Friesian (HS) available at NDRI.

Loose housing system was being followed, and bulls were kept in open paddocks with roof over mangers. This system provides adequate exercise for animals, which are exposed to all types of climate. *Adlib* feeding of good quality green fodder throughout the year is provided along with silage during the lean period. In order to ensure good health of bulls, prophylactic and sanitary measures are taken for all the bulls.

Body Size Measurement

During the experimental period, the body size (height and girth) measurements were monitored fortnightly. Body weight was taken on platform type, computerized weight management system, balance in the morning (from 07:00 – 09:00 hours) before feeding. Girth and height at withers were measured with flexible cloth tape in centimeters.

Testicular Size Measurements

The following testicular measurements of all the bulls were taken fortnightly. i) Scrotal circumference, SC, ii) Testis length (Right and Left), TL,
iii) Testicular width, TW, iv) Testis thickness (Right and Left), TT, v) Scrotal Skin thickness, SST and vi) Paired Testicular Volume, PTV.

The bulls were restrained well with the help of bull attendants in a crate and the readings were taken at standing position. The testicular length, width and thickness were measured within scrotum by bringing the testicles on one side at bottom. The scrotal skin thickness was subtracted from the testis length, testis width and testis thickness to get actual testis length, testis width and testis thickness, respectively.

Scrotal Circumference (SC): The scrotal content was palpated to ensure normal position. Then the testes were pulled into the bottom of the scrotum gently and evenly so that the testicles were side by side and scrotal skin was devoid of any wrinkles. Then the area of greatest circumference was measured with flexible plastic plated cloth tape in centimeter (Coulter et al., 1987).

Testicular Length (TL): The *in situ* proximal-distal length of left and right testicles was measured (Podany, 1964), by Electronic Digital Caliper in centimeter. Both testicular measurements were averaged. Care was taken to exclude the epididymides in measuring the length.

Testicular Width (TW): The medial-lateral width of left and right testicles was measured *in situ* with Electronic Digital Caliper in centimeter (Fields et al., 1979), on both testes at the point of maximum dimension. Both testicular widths were averaged.

Testicular Thickness (TTH): The anterior posterior thickness of both left and right testicles within scrotum was measured by Electronic Digital Caliper in centimeter. The thickness of both testicles was averaged.

Scrotal Skin Thickness (STH): The testicles were pushed upward and the bottom of the scrotal skin was pushed down. Then scrotal skin thickness was measured by Electronic Digital Caliper in centimeters.

Paired Testicular Volume (PTV): Two formulae were frequently used to compute paired testicular volume: (i) PTV (V1) = $0.0396(\text{average L})(SC)^{2}$, formula of Prolate spheroid using scrotal circumference, SC; (Lunstra *et al.*, 1978) and (ii) PTV (V2) = $4/3\,(\Pi)(L/2)(W/2)^2$, formula of Prolate spheroid using length and width of testis (Bailey *et al*. 1998). In their comparison of Caliper and Ultrasonographic measurements of bovine testicles and a mathematical formula to estimate testicular volume and weight *in vivo*, Bailey et al. (1998) found that the prolate spheroid formula is more reliable in determining testicle volume (r^2=0.89; P<0.05). They also pointed out that testicular volume and weight are highly correlated (r^2=0.98; P<0.05). Therefore, a modification of prolate spheroid formula was used in this study to predict weight, (r^2=0.91; P<0.05).

Total Testicular Weight (TTWT): The high correlation of testicular measurements (SC, TL and TW) with total testis weight has been utilized to predict the TTWT in live animals. Only one formula (Bailey et al., 1998) is available which computes TTWT from TL and TW: TTWT = $0.5533(L)(w)^2$, where L = length of the testicle and w = width of the testicle. This formula was applied in this study to compute total testis weight (TTWT).

Statistical Analysis

Forward Stepwise Multiple Regression Analysis, as described by Draper and Smith (1981), was used. Multiple regression equations were constructed to predict SC, PTV, and TTWT and body weight from age, body size and testicular measurements. Regression analysis was used to predict traits, which were otherwise impossible or difficult to measure in live animals, especially in large livestock. The analysis was continued in a stepwise manner until all useful variables were entered. At each step, the variable added was the one, among those not yet included, which would make for the greatest reduction in error sum of squares. In other words, the variable added at each step was the one, among those not yet included, which in combination with already included, would maximize R^2, or, equivalently, it was the variable, among those not yet included, having the largest partial correlation with the dependent variable being predicted. Based on R^2 values, the best-fitted prediction equations were selected.

The following linear regression model was fitted: $Y = X\beta + e$; $R2 = ss\text{-}r / ss$ Y = observed vector of the dependent variables (SC, PTV, TTWT, WT)

X = incidence matrix of one or a combination of independent variables

β = Vector of unknown parameters ($\beta 0$, $\beta 1$, $\beta 2 \ldots \beta n$) e = error term

ss-r = Sum of squares due to regression ss = Total sum squares

R^2 = Coefficient of determination

Results and Discussion

Prediction of scrotal circumference (SC) from age and linear body size measurements

Results of forward stepwise multiple regression analysis for Sahiwal and Karan Fries bulls using age (months), body weight (kg) and measurements of body size (height, cm; girth, cm) as independent variables to predict SC (dependent variable) are presented in Table 1. Stepwise prediction equations were developed based on the significance of partial correlation coefficients between SC and age and body size measurements. Either linear, when each fitted as a single covariate or multiple effects of age, weight, chest girth and height all affected ($P<0.001$) scrotal circumference. Of the four, chest girth had the greatest effect. In both breeds, the first step of the stepwise regression procedure picked up chest girth, with the highest partial correlation of 0.94 and 0.88 with SC in Sahiwal and KF, respectively. This equation explained 72.0% and 77.3% of the total variation in SC in Sahiwal and KF, respectively.

Table 1. Coefficients of forward stepwise regression analysis using age (months) and weight (kg), girth (cm) and height (cm) to predict scrotal circumference (cm)

Breed	Step	Traits	b±S.E.	R^2 Value (%)
Sahiwal	I	Girth	0.204 ± 0.010	72.0
	II	Age	0.054 ± 0.030	73.0
		Girth	0.165 ± 0.021	
KF	I	Girth	0.197 ± 0.007	77.3
	II	Weight	-0.012 ± 0.005	78.0
		Girth	0.277 ± 0.034	
	III	Weight	-0.012 ± 0.005	78.4
		Height	0.106 ± 0.053	
		Girth	0.277 ± 0.034	

Little improvement in the accuracy of prediction was achieved when the second highly correlated variable, age (0.173) and weight (-0.167) (data not presented) in Sahiwal and KF, respectively, were included in the model. The inclusion of the corresponding traits resulted in increase in the R^2 value only by 1%. Body weight and age continued to influence SC (*P*<0.05) (data not presented) with girth in the model though its effect was diminished. In general SC appears to be most affected by body size, although age remains an important factor.

Stepwise regression was terminated at step 2 in Sahiwal, as the partial correlation of SC to height becomes non-significant. But the regression analysis was further continued for KF bulls by including the remaining variable, height, as the partial correlation after the second step of the regression analysis was found significant between SC and height, without significant improvement in accuracy of the prediction equation. Because of this fact the first equation was taken as the best prediction equation of SC from body measurements in Sahiwal and KF bulls (Table 1).

Prediction of paired testis volume, PTV (cm^3) from age, body size and Testicular measurements in Sahiwal and KF bulls

Several prediction equations were constructed using age, weight, height, girth and testicular size measurements (length, width and SC) to predict paired testicular volume in Sahiwal (Table 2) and Karan Fries (Table 3) bulls. Based on the significance of partial correlation coefficient, SC (*P*<0.001) (data not presented) was the first trait picked up in the stepwise regression analysis with partial correlation coefficient of 0.967, explaining the 95.0% and 93.5% of the variation in paired testicular volume for Sahiwal and KF bulls, respectively. This study showed that there existed a linear relationship between SC measurements and testicular volume in Sahiwal and KF bulls.

Table 2. Coefficients of forward step wise regression analysis using age (months), weight (kg) and testicular size(cm) to predict paired testicular volume, PTV (cm) in Sahiwal bulls

Prediction of PTV_1

Step	Traits	b±S.E.	R^2 Value (%)
I	SC	33.771 ± 0.627	95.0
II	Age	28.003 ± 3.976	
	SC	27.623 ± 0.975	96.4
III	SC	25.217 ± 1.036	
	Length	24.544 ± 3.533	
	Age	1.1596 ± 0.239	96.9

Prediction of PTV_2

Step	Traits	b±SE	R^2 Value (%)
I	Width	122.357 ± 3.583	88.8
II	Length	32.143 ± 2.180	95.3
Width		90.645 ± 3.150	
III	Length	24.903 ± 2.370	96.1
Width		87.387 ± 2.931	
	Age	0.917 ± 0.163	
IV	SC	2.177 ± 0.839	96.3
Length		21.412 ± 2.687	
Width		84.328 ± 3.109	
V	SC	2.878 ± 0.844	96.5
Length		22.517 ± 2.633	
Width		84.478 ± 3.019	
Weight		-0.155 ± 0.710	
	Age	1.55353 ± 0.318	

Prediction of Total Testis Weight, TTWT (g) from age, body weight and Testis size Measurements

In the stepwise regression analysis to predict total testis weight from age, body weight and testicular measurements, it was observed that step 1 alone could account for 88.5% and 90.8 % of the variation in testes weight, in Sahiwal and KF bulls, respectively. But step 2 seems to be the best fit model as inclusion of length to width increased the coefficients of determination from 0.885 to 0.963 in Sahiwal bulls and from 0.908 to 0.948 in KF bulls. Overall, SC was found to be best predicted from heart girth (G), body weight from G and age of the animal, PTV from SC, TL and TTWT and TTWT from TL and TW (Tables 4 and 5).

Table 3. Coefficients of forward step wise regression analysis using age (months), weight (kg) and testicular size (cm) to predict paired testicular volume, PTV (cm) in KF bulls

Prediction of PTV_1

Step	Traits	b±S.E.	R^2 Value (%)
I	SC	35.425 ± 0.661	93.5
II	SC	26.463 ± 1.327	95.0
	Length	33.645 ± 4.475	
III	SC	24.102 ± 1.281	95.6
	Length	28.995 ± 4.019	
	Age	1.338 ± 0.220	
IV	SC	26.082 ± 1.337	96.1
	Length	36.402 ± 4.464	
	Width	-29.799 ± 7.613	
	Age	1.308 ± 0.212	
V	SC	27.635 ± 1.353	96.3
	Length	40.857 ± 4.465	
	Width	-29.987 ± 7.357	
	Age	1.767 ± 0.237	
	Height	-2.200 ± 0.570	

Prediction of PTV_2

Step	Traits	b±S.E.	R^2 Value (%)
I	Width	152.580 ± 3.187	92.0
II	Length	27.659 ± 2.635	94.9
	Width	105.022 ± 5.205	
III	Age	0.751 ± 0.141	95.5
	Length	22.010 ± 2.689	
	Width	102.810 ± 4.890	
IV	Age	1.520 ± 0.193	96.1
	Girth	-1.168 ± 0.215	
	Length	28.200 ± 2.760	
	Width	107.301 ± 4.652	
V	Age	1.185 ± 0.233	96.2
	Weight	0.158 ± 0.063	
	Girth	-1.971 ± 0.384	
	Length	27.742 ± 2.730	
	Width	108.713 ± 4.625	

Table 4. Coefficients of forward stepwise regression analysis using age, weight and testis size to predict TTWT (g) in Sahiwal bulls

Step	Traits	b ± S.E.	R^2 Value (%)
I	Width	129.246 ± 3.785	88.5
II	Length	33.953 ± 2.309	95.3
	Width	95.749 ± 2.931	
III	Length	26.306 ± 2.504	96.1
	Width	92.306 ± 3.096	
	Age	0.969 ± 0.173	
IV	SC	2.299 ± 0.886	96.3
	Length	22.617 ± 2.839	
	Width	89.076 ± 3.284	
	Age	0.751 ± 0.189	
V	SC	3.040 ± 0.892	96.5
	Length	23.785 ± 2.78	
	Width	89.234 ± 3.189	
	Weight	-0.164 ± 0.052	
	Age	1.641 ± 0.336	

Table 5. Coefficients of forward stepwise regression analysis using age, weight and testis size to predict TTWT (g) in KF bulls

Step	Traits	b ±SE	R^2 Value (%)
I	Width	29.216 ± 2.302	90.8
II	Length	29.216 ± 2.302	94.8
	Width	110.934±3.541	
III	Length	21.557 ± 1.034	96.0
	Width	98.222± 2.096	
	Age	2.336 ± 1.273	
IV	SC	1.939 ± 0.886	96.7
	Length	20.764 ± 4.339	
	Width	90.760 ± 3.454	
	Age	1.751 ± 0.189	
V	SC	2.556 ± 2.891	96.8
	Length	23.785 ± 2.781	
	Width	89.423 ± 5.289	
	Weight	-1.255 ± 1.052	
	Age	1.641 ± 0.336	

Even though age as the third most useful independent variable in prediction of TTWT was included in step III of the stepwise regression analysis, it could not influence the accuracy of prediction much. The stepwise analysis continued up to step 5 by including SC and body weight in steps 4 and 5, respectively. But the increases in coefficients of variation were not significant in both breeds. Hence, model II was taken as the best prediction equation to predict TTWT from TL and TW. The importance of SC was obscured in prediction of TTWT because of the fact that the current total testis weight was estimated from TL and TW only. Even then, when we consider SC in a single effect model using pair correlation of SC and TTWT, it accounted about 77% of the variation in TTWT.

Prediction of body weight (WT) from age and body size measurements As can be seen from Table 6 body weight was sufficiently predicted from model I. It was observed that there was highly significant partial correlation coefficient of 0.956 and 0.960 between body weight and chest girth in Sahiwal and KF bulls, respectively. As the result, chest girth was taken first in stepwise regression analysis accounting for 91.6% and 95.2% of the variation in body weight in Sahiwal and KF bulls.

Table 6. Coefficients of forward stepwise regression analysis using age and body size measurements to predict body weight (Kg)

Breed	Step	Traits	b ± S.E.	R^2 Value (%)
Sahiwal	I	Girth	5.786 ± 0.142	91.6
	II	Age	3.316 ± 0.226	96.5
		Girth	3.379 ± 0.188	
	III	Age	3.307 ± 0.220	96.7
		Height	1.828 ± 0.558	
		Girth	2.724 ± 0.271	
KF	I	Girth	6.513 ± 0.103	95.2
	II	Age	2.141 ± 0.214	96.8
		Girth	4.970 ± 0.176	
	III	Age	2.239 ± 0.213	96.9
		Height	1.703 ± 0.599	
		Girth	4.135 ± 0.341	

The partial correlation coefficient between body weight and age was higher causing further forward regression analysis with the increment of 4.9% and 1% in R^2 values in Sahiwal and KF bulls, respectively. When age was included in step II, significant partial correlation ($P<0.01$) was observed between body weight and height and then in step III all the three parameters were included. But the increase in R^2 value was very insignificant indicating Model II as the best prediction equation for body weight in Sahiwal. As the increase in coefficient of determination was not statistically significant after the first step of the analysis, model one alone was found sufficient for KF breed to predict weight based on the chest girth measurement. This finding is advantageous in that the measurement of girth is easy and applicable without any infrastructure barrier. The availability of the weighing scale for livestock in general and that of larger animals in particular is a persisting problem for performance evaluation at field level. The ease and accuracy of measurement of chest girth with flexible cloth tape can meet the challenge of this problem.

Table 7. Best selected equations in estimating potential fertility of breeding bulls using age, weight, linear body size and testicular measurements

Breed	Traits	Selected Equations	R^2 Value (%)
Sahiwal	SC	Y= -3.96990 + 0.20414 (G)	72.4%
KF	SC	Y= -3.62808 + 0.69739 (G)	77.3%
Sahiwal	WT	Y = -320.14 + 30.14 (Age) + 0.30378 (G)	96.5%
KF	WT	Y = -728.13409 + 6.51311 (G)	95.2%
Sahiwal	V1	Y = -613.12553 + 33.77196 (SC)	95.0%
KF	V1	Y = -642.80489 + 35.42521 (SC)	93.5%
Sahiwal	V2	Y = -500.51626 + 32.14 (TL) + 90.64 (TW)	95.3%
KF	V2	Y = -514.03991+27.66 (TL) + 105.022 (TW)	94.8%
Sahiwal	TTWT	Y = -528.69545 + 33.95 (TL) +95.75 (TW)	95.2%
KF	TTWT	Y = -542.98034+29.23 (TL) +110.934 (TW)	94.8%

Conclusion

This study has shown the possibility of predicting body weight from easily measured body measurements like chest girth and height. Chest girth was also found to have high correlation with scrotal circumference, which otherwise is difficult to measure at least in some bulls. It also showed the advantages of testicular measurements like scrotal circumference, testis length and testis width, in reasonably predicting paired testicular volume and testis weight, which have direct relationship with the capacity of that particular animal to produce spermatozoa. Bull selection has a greater impact on the genetic improvement of a herd than usually realized by livestock producers. As a bull determines the fate of many individual females and calves by contributing a larger portion of the genes to the herd, selection of bulls is a first prerequisite in improvement of farm animals. In this study the potential fertility of a bull was predicted from a combination of direct and indirect measurements of testis size. Body measurements provided an indirect estimate testis size. Accordingly several equations were developed and best models were presented. These models help to predict potential fertility of bulls so as to facilitate culling decisions at an early age. These decisions help reduce costs of bull management, in terms of labour, space and time. The study has high relevance under Ethiopian condition as the methodology is simple to apply even at on-farm condition. Based on this, a similar research is in progress at Bako Agricultural Research Center to test the method on Horro bulls and their crosses. Since these correlations of testis size measurements with body measurements are not close to unity, it is always necessary to substantiate the implied correlations with the actual fertility status of bulls.

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