Original Research

'Breeders Toolkit': A Cloud-Based Breeding Toolkit for Estimation of Various Breeding Parameters

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Abstract

The enormous potential of the science of animal genetics and breeding remains untapped especially in developing countries. Concerns about the unmet productivity potential of animals are increasing as the gap between demand and supply of animal products increases. Since animal husbandry sector is largely unorganized, farm managers and small scale entrepreneurs are unable to select genetically superior animals as parents for the next generation. An integration of ICT with animal breeding may be the solution to such problems. In this regard, a cloud-based, simple to use and flexible tool named "Breeder's Toolkit" was developed which estimates important breeding parameters like selection differential, response, breeding values, economic values for traits, average generation interval, approximate parturition date and age with minimal data input. The developed toolkit is free, easily accessible, accurate and simple to use. Users even with minimal knowledge of animal breeding methodologies can derive benefits from the cloud-based tool. Alpha-testing and comparison with the standard (wherever applicable) was carried out. Accuracy of the tool was found to be 100% with a p value of 1 and mean difference of 0.00 for all comparisons. The use of such a tool would simplify complex calculations, aid decision making and help in scientific selection of animals wherever knowledge dissemination is sparse and inefficient.

Key words: Age, Breeding Tools, Breeding Value, Response, Selection Differential

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Introduction

Developed countries, with the use of various advanced breeding techniques, biometrical methods, and computer aided innovations have seen tremendous improvements in livestock productivity over the years. Same cannot be said for developing countries where the potential of livestock is still largely untapped and concerns for food safety are rising alarmingly (Kitzes *et al.*, 2008, Kamilaris and Prenafeta-Boldú, 2018), since breeding decisions are still based mostly on intuition rather than on scientific lines especially in the unorganized farms. This may mainly be attributed to the dearth of simple and consolidated breeding tools, and inadequate dissemination of information to farm managers. The science of animal breeding and genetics aims to improve the genetic merit of animals by utilizing the genetic differences among individuals through various scientific techniques for selection and breeding (Thekkoot, 2018). This requires extensive knowledge of different aspects of the subject including complex methodologies required to estimate various parameters essential for making breeding decisions at farm level.

However, estimation of such parameters is not only complicated and tedious, but also requires advanced knowledge of breeding and genetics. This complexity becomes a major constraint for farm managers with little or no knowledge of animal breeding who are unable to make such estimates and also do not have access to scientific tools/ softwares that could facilitate scientific selection of animals. This often leads to insufficient realization of true genetic worth of animals and genetically superior animals often end up being slaughtered. All this has direct implications on farm economies and subsequently the national economy in developing countries. Under such conditions, genetic advancement of animals (ICAR, 2015) through its integration with Information Communication Technology (ICT) may prove to be a major game changer. ICT is causing a revolution in all areas of science, and agriculture is no exception (Gebbers and Adamchuk, 2010). Now that internet accessibility is improving even in remote areas and electronic devices are rapidly becoming cheap and accessible, cloud-based tools may cause unprecedented improvement in the current breeding practices across the world. Therefore, keeping in view the above facts, an effort has been made to equip breeders and farm managers with a simple, easy and consolidated breeding toolkit, to make cumbersome complex calculations at fingertips.

Materials and Methods

Model used and Requirement Analysis

The Software Development Life Cycle (SDLC) approach (Barjtya, 2017) followed for the development of this web-based toolkit was the Waterfall Model or the linear-sequential life cycle model. Requirement analysis was carried out to identify the constraints faced by farm managers in the application of breeding techniques.

System Design and Implementation

Breeder's toolkit was developed as a combination of multiple applets using PHP (version 7.2) which runs on multiple operating systems *viz.* Windows, Linux or Mac OS. The web interface was written on a Windows 10 localhost under XAMPP (Cross platform - Apache, MySQL, Perl and PHP) server using HTML5, CSS and PHP.

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Tools

A total of 5 tools were created with a 'Homepage' for redirection to relevant portals. In-house developed PHP scripts were written and standard formulas were incorporated into the algorithms developed for each tool. Information about the estimates made by the toolkit was made available in the form of hover buttons available on each page.

Selection Differential, Response & Breeding Values Tool

Selection differential, response and breeding values estimators were created such that the end-user could get an understanding of the genetic progress at the farm. Algorithms for the calculations were created such that 'Selection Differential' could be calculated as the average superiority any number of selected parents in a population. Algorithm for the estimation was done using the formula, $S = P_s – P_m$ where P_s is the average phenotypic value of any number of selected parents and P_m is the value for the population. The expected evolutionary 'Response' (*R)* calculations for the developed tool were made by estimating the inherited part of the selection differential (*S)* (Tomar, 2004) but with a user-defined heritability value (h^2) according to the breeder's equation $R = h^2S$ (Falconer and Mackay, 1996). The estimation of 'Breeding Value' was done using formulas for individual selection also called mass selection. The script created for the purpose of estimation of individual breeding value was taken as deviations from the population mean times the heritability of the trait.

Economic Value Tool

Code for the estimation of economic values for different traits was written on the basis of prices of different commodities prevailing in the market. Since these values may change from time to time and place to place, therefore scripts were written in such a way that book values of traits at for different traits could be input by the user. The economic value calculator tool was created for birth weight, weaning weight, 6 month weight, 9 month weight and 12 month weight. Code for the calculation of economic values was then written based on the survivability, price per kg and the number of days to attain that value (Ganai, 1998).

Age Tool

The script for age calculation was written in such a way that age in years, months and days, as well as age in days could be displayed to the end user for any user specified dates. Leap year was also taken into account while writing the code for age estimation.

Expected Parturition Date Tool

The parturition date estimating tool was created for cattle, sheep, goat, buffalo, horse, rabbit, camel, llama, dog, cat and elephant by taking the average gestation periods as 282 days (ICAR, 2013), 5 months, 150

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days, 310 days (ICAR, 2013), 340 days (ICAR, 2013), 32 days, 378 days (ICAR, 2013), 11 months, 63 days, 65 days and 22 months, respectively.

Generation Interval Tool

In-house developed script for the estimation of average generation interval was written for any number of animals using the average age of the parents at birth of their first offspring. The program was created in such a way that estimates of the average generation interval for any number of animals in the population could be made and not just a single parent. This was done to ensure the requirement of the end user could be met as per the number of animals on the farm.

Integration and Testing

All the units developed in the implementation phase are integrated into a system after testing of each unit. Post integration the entire system is tested for any faults and failures. Data for conducting alpha tests on some portals of the developed tool was collected from Mountain Research Center for Sheep and Goat, Shuhama, Alusteng, Srinagar (MRCGS), for Corriedale breed of sheep while random data was taken for other portals. Alpha testing for the applets developed for selection differential, response and breeding values, was done based on animals selected out of the records for birth weight of Corriedale sheep from 2014-2017. Phenotypic average for all animals within this date range was calculated to be 3.67 kg. Birth weight was selected for the purpose because it is one of the most initial traits that can be utilized for selection and it reflects the survivability of lambs (Khan *et al.*, 2011). Heritability value for birth weight in Corriedale sheep at MRCGS was taken as 0.117 (Risam *et al.*, 1999).

Test data for the estimation of economic values was taken for Corriedale breed of sheep on MRCGS farm from 2011 to 2017. Phenotypic averages of birth weight, weaning weight, 6-month weight, 9-month weight and 12-month weight were taken from this data. The economic values were estimated manually as well as Breeder's Toolkit. In order to test the accuracy of the tool for calculation of age, standard manual calculations (standard) (Falconer and Mackay, 1996) were made for 100 random dates. The accuracy of the developed tool for the estimation of approximate parturition date was checked by comparing the results of the developed tool to manual calculations for all species as provided within the developed tool. The applet for estimation of generation interval was alpha tested using test data for 100 random dates manually as well as Breeder's Toolkit and comparing the results. A standard example from Textbook of Animal Breeding (Tomar, 2004) was also taken and the results compared. Independent sample T-test was used to compare the results.

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Deployment of System

The system was deployed on a Virtual Private Server with Linux (Ubuntu) Operating System. The configuration included, 25 GB SSD, 1 CPU, 1024 MB memory and 1000 GB bandwidth.

Result and Discussion

On requirement analysis we found that farm managers and breeders did not have access to simplified and consolidated breeding tools. A general lack of awareness among small scale livestock enterprise managers regarding the use and importance of making biometrical estimations for selection and breeding was also seen. A dire need for the development of simplified tools which could be used by farm managers easily was felt.

Cloud-based Toolkit

A cloud-based toolkit named "Breeder's Toolkit" was designed and developed (http://agbskuastk.org//toolkit). It is a comprehensive toolkit to facilitate decision making in animal breeders and to help researchers make calculations regarding some important aspects of animal breeding and genetics. Breeder's Toolkit is a user friendly, free and accurate program which can be accessed from any device having a browser and an active internet connection. On requirement analysis, a similar authentic and accurate tool providing multiple genetic calculations on a single and simplified platform could not be traced which makes the developed tool unique. Some tools available online were found to be complicated and difficult to use for users with little knowledge of the science of Animal Breeding. An important feature of the developed tool is its simplicity of design and use. The homepage redirects the user to multiple portals for the ease of access *viz.* breeding value, selection differential, response and economic value, age, parturition date and generation interval. Hover buttons available provide additional information within each portal.

Tools

Selection Differential, Response & Breeding Values Tool

Understanding the selection differential of a group of individuals from the population mean enables the selection of animals of superior genetic merit for any particular trait. This is better than selection purely on the basis of intuition. Maximizing the rate of genetic gain is a major objective of animal breeders. Genetic gain implies an improvement in the performance of the animals and is a Breeder's central paradigm. The prediction of selection response is considered as the final goal of selection because it gives the breeder an idea regarding the effectiveness of selection at the farm (Nyquist and Baker, 1991). Breeders toolkit was, therefore, developed in such a way that selection differential (Fig. 1) and response to selection (Fig. 2) for any number of animals on the farm could be generated.

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Fig. 1: Calculation of selection differential

Fig. 2: Calculation of selection response

Selection of the best animals, needed to induce genetic gain, requires estimating their breeding value, which allows ranking them according to their genetic superiority (Popescu, 2014). A (additive genetic effect), also referred to as breeding value, gives the value of an animal in a breeding program for a particular trait. Therefore, the animals with an above average breeding value for a particular trait have a better chance of producing more productive progeny. The selection of the animal based on his own performance is considered one of the most accurate methods for the selection of animals. The simplest and most direct way of breeding farm animals is by mass selection, *i.e*. by selecting the breeding stock purely on the basis of their own phenotypic (Rendel and Robertson, 1950). The developed TOOLKIT estimates the breeding values (Fig. 3) of any number of animals and enlists them at the front-end to the user, thereby predicting the genetic superiority of the animal above the population mean for the selected trait.

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Fig. 3: Calculation of breeding values

Economic Value Tool

To determine which traits have the greatest economic influence on the production system, and economic values estimator was developed. These would help in giving weightage to traits for effective multi-trait selection. The prices per unit may vary from farm to farm as well as from time to time and therefore, flexibility was provided to the end user to enter them as per the market price. The economic value calculator of Breeder's Toolkit generates economic values of multiple body weight parameters. These economic values can intern help the breeder to construct relevant selection indices for selection of animals based on many traits (Lin, 1978).

Fig. 4: Calculation of economic values for specific traits

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Age Tool

Age calculations are very important when it comes to important breeding decisions. This is manifested by the fact that age is required for understanding generation intervals, age at sexual maturity, growth rate (Hazel, 1943) etc., which are important economic indicators of a farm and are vital for the economic progress of a farm. In this regard, a simple to use age calculator was developed yielding results years, months and days, and only in days. Age may be calculated between any two user-specified dates (Fig. 5).

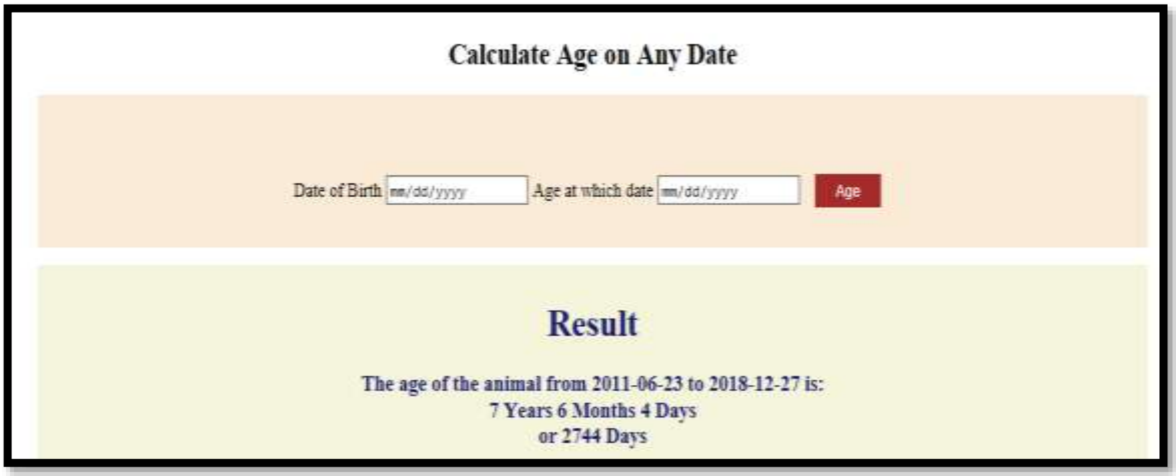

Fig. 5: Calculation of age

Expected Parturition Date Tool

An approximate date of parturition would help the farm manager to plan the arrival of a new-born animal into the farm. The gestation period varies between species and it is important to know the approximate date of parturition so as to prepare the farm manager for the arrival of a new-born in the farm. Breeder's Toolkit provides approximate dates of parturition for multiple species as per the date of successful service (Fig.6).

Fig. 6: Calculation of expected parturition date

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Generation Interval Tool

The generation interval facilitates to calculate the genetic response per year (Waaij, 2014). Understanding the generation interval in a farm would help in understanding and improving the reproductive potential of the animals at the farm and thereby undertake strategies to reduce the generation length. This will generally increase the rate of genetic progress per year. The rate of genetic improvement to be expected from a selection programme is often interpreted in terms of the selection differentials and the generation lengths (Rendell and Robertson, 1950). A short generation length means that animals selected for breeding are mated in the herd at a younger average age (Fig. 7).

Fig. 7: Calculation of average generation interval

Integration and Testing

Selection differential and response calculations both manually as well as Breeder's Toolkit yielded same results as indicated in Table 1. Statistical analysis of the breeding values as produced by the two methods showed the mean difference equal to 0.00 and a p value of one which indicates that the two results were the same (null hypothesis accepted) (KSU, 2018). The breeding value estimates for the first 10 animals are also given (Table 2).

Table 1: Selection difference and response comparisons

	Breeder's Toolkit	Standard
Selection Differential	0.44	0.44
Response	0.05	0.05

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Table 2: Breeding value comparisons for birth weight in Corriedale sheep

Animal	Breeding Values for Birthweight	
	Standard	Breeder's Toolkit
1	3.73	3.73
2	3.72	3.72
3	3.85	3.85
4	3.78	3.78
5	3.88	3.88
6	3.59	3.59
7	3.59	3.59
8	3.74	3.74
9	3.73	3.73
10	3.59	3.59
11	3.53	3.53
12	3.53	3.53
13	3.65	3.65
14	3.71	3.71

The mean phenotypic values estimated were 3.76, 12.70, 15.86, 18.37, 20.15 kg to birth weight, weaning weight, 6 month weight, 9 month weight and 12 month weight. These values were used for testing the tool developed for estimation of economic values. Economic values value estimates also yielded similar results for estimates made by two different techniques. The results are indicated in Table 6. Statistical analysis of economic values evaluated by the two methods also indicated a mean difference equal to 0.00 and a p value of one. The results, on comparison to manual calculations of age were found to be similar for all dates with a mean difference of 0.00 and p value =1. First 5 results for the same are presented in Table 3.

Table 3: Age estimation comparison

		Standard		Breeder's Toolkit	
Birthdate	Date	Age (y, m, d)	Age (days)	Age (y, m, d)	Age (days)
1/16/2016	1/17/2016	0 y, 0 m, 1 d	1	0 y, 0 m, 1 d	1
12/2/2015	12/5/2017	2 y, 0 m, 3 d	734	2 y, 0 m, 3 d	734
4/2/2012	12/20/2018	6 y, 8 m, 18 d	2453	6 y, 8 m, 18 d	2453
4/25/2000	8/3/2017	17 y, 3 m, 9 d	6309	17 y, 3 m, 9 d	6309
8/23/2009	12/17/2018	9 y, 3 m, 24 d	3403	9 y, 3 m, 24 d	3403
7/28/2006	12/18/2018	12 y, 4 m, 20 d	4526	12 y, 4m, 20 d	4526

Approximate parturition dates were estimated both manually and using the tool. Although manual calculations took considerably longer times, the results were found to be similar (Mean difference = 0.00 and p value =1) as indicated in Table 4. The results of average generation interval also yielded similar results on comparison with the manual results. The results are indicated in Table 5.

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Table 4: Approximate parturition dates

Species	Date of Successful Service	Parturation Dates	
		Manual Calculations	Breeder's Toolkit
Goat	21-12-2018	20-05-2019	20-05-2019
Sheep	21-12-2018	21-05-2019	21-05-2019
Cattle	21-12-2018	29-09-2019	29-09-2019
Buffalo	21-12-2018	27-10-2019	27-10-2019
Mares	21-12-2018	26-11-2019	26-11-2019
Camel	21-12-2018	3/1/2020	3/1/2020
Llama	21-12-2018	21-12-2029	21-11-2019
Rabbit	21-12-2018	22-01-2019	22-01-2019
Cat	21-12-2018	24-02-2019	24-02-2019
Dog	21-12-2018	10-12-1900	22-02-2019
Elephant	21-12-2018	21-10-2020	21-10-2020

Table 5: Generation interval result comparison

No. of Data Points	Generation Interval		
	Standard	Breeder's Toolkit	Tomar, 2004
100	2.74	2.74 years	
10		5 years	5.0 years
90	7 years	7.0 years	

Table 6: Comparisons for economic value estimates

Trait	Economic Value	
	Standard	Breeder's Toolkit
Birth weight	0.76	0.76
Weaning Weight	0.31	0.31
6 month Weight	0.12	0.12
9 month Weight	0.07	0.07
12 month Weight	0.04	0.04

Conclusion

Scientific selection and breeding of animals is based on tedious calculations which are often difficult to understand and interpret. Lack of knowledge regarding such estimates has prevented animal generic resource in developing countries to reach its full potential. Development of ICT based tools to facilitate such calculations may change the current scenario. Keeping all this in view, a cloud based toolkit was developed to provide genetic estimates to farm managers, breeders and students. Breeder's Toolkit is a simple, easy to use platform which is freely available online. Breeder's Toolkit was designed to cater to the specific needs of breeders, farm managers and scholars especially in developing countries. It has the flexibility for incorporation of more biometrical methodologies as per future requirements of the users and its use by breeders especially those associated with small scale enterprises is strongly recommended.

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