



# Tools and resources for teaching genetics in veterinary sciences in India: A critical analysis of deficiencies and possible solutions

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## Abstract

Recent developments in Animal Genetics and Breeding (AGB) in 21<sup>st</sup> Century have made these areas logical to be unavoidable for modern livestock husbandry. AGB teaching consists of knowledge in three fields' viz., conventional animal breeding, application of molecular genetics in livestock production and reproduction of superior genetic material. Teaching in this subject currently has however, been skewed either to animal breeding or to molecular genetics resulting in incomplete knowledge of both the fields. Simple laboratory practical exercises on *Tribolium* and *Drosophila*, which were routinely experienced about 20 years back, are now missing in most of the colleges/universities. Livestock farm facilities for each species like cattle, buffalo, sheep, goat and pig should be strengthened to understand the genetic mechanism of quantitative traits. Advanced statistical tools, which are required to understand the complex structure and function of genes and genome are missing in the curricula. Use of the latest software to understand the molecular mechanisms underlying important traits in domestic animals need to be emphasized in syllabus. Basic knowledge of computer languages like R, C++, FORTRAN and Java must be compulsory for the students of AGB to understand and formulate the parameters for the software. Experience of collecting huge phenomic data from the livestock farms and its statistical analysis is missing in the curricula. A compulsory course on "Livestock Farm Practices" in line with Under Graduate students should be kept in 1<sup>st</sup> year for Post Graduate students also. Furthermore, exposure visits should be organized to state of the art farms of Government and industry to cover all the livestock species in order to sensitize students for efficient phenomic data recording. A skill development course should be designed at Post Graduate level using specialized techniques of AGB for fulfilling the gap of manpower in industry.

**Key words:** Teaching, animal genetics, deficiencies, solutions

Under Graduate students have the fear of

unknown origin towards Genetics and Breeding discipline, which may probably be due to little knowledge of Elementary Mathematics and Statistics. Therefore, they should be given exposure of these subjects before starting the Animal Genetics and Breeding (AGB) courses. The time requirement for teaching Animal Genetics and Breeding to Under Graduate students is less in view of mathematical/statistical derivations. Furthermore, Animal Breeding courses should be covered in 3rd year after completion of mathematical/statistical / reproduction / LPM courses.

Though PowerPoint presentation is an efficient tool for teaching, however, all the lectures should not be delivered through this technique, especially those which include mathematical/statistical calculations. Board based teaching is recommended for such courses. Updated study material and practical manuals should be available separately for Undergraduate and Postgraduate students online on a public portal like "E learn vet" to make teaching uniform in the country. Emphasis should be given for teaching through videos and animations to understand complex concepts of genetics. The computational facility needs to be strengthened along with advanced software for high-end computing to teach Postgraduate students. Wet laboratory facilities for Cytogenetics and Molecular Genetics including advanced instruments should be developed/updated at each college. Teachers in sufficient number should be given proper exposure and training of recent developments in the country or abroad.

Genetics is an important branch of science dealing with the laws of inheritance that were

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rediscovered at the beginning of 20<sup>th</sup> century. More than a century after its existence, when William Bateson coined the term “genetics” in 1906, the field of genetics has progressively expanded to cover many areas along with the study of inheritance. Since the discovery of the structure of the genetic material i.e., deoxyribonucleic acid (DNA) by Watson and Crick, the science of genetics has become increasingly molecular. This discipline has grown from hybridization experiments that gave birth to laws of inheritance and has progressed through cytogenetics, quantitative genetics to molecular genetics. The science of molecular genetics and the recombinant DNA techniques are the foundation of modern biotechnology. There is hardly any other subject area in basic sciences with more influence on shaping our knowledge of living systems than genetics.

Veterinary sciences and animal husbandry are also not exceptions and Animal Genetics and Breeding (AGB) is one of the most applicable subjects for 21<sup>st</sup> century livestock industry. Recognizing the significance of this subject, it is extremely important to perform a critical analysis of the tools and resources available for teaching genetics in veterinary sciences in India. This will pave the way to identify the deficiencies and ultimately possible interventions for their mitigation.

#### **Teaching Animal Genetics and Breeding (AGB): Tools and resources**

India is bestowed with a large inventory of animal genetic resources (AnGR). India contributes a significant proportion to the global population of livestock and poultry. With vast agro-climatic diversity, India harbors a total of 183 breeds of livestock and poultry. With 108.7 million buffaloes [1], India stands at the prime position all over the world. Similar top rankings are held with regards to other livestock species. However, 70-80% of the AnGR in India (Breed survey report, 2013) are non-descript (74.92%, 43.37%, 41.08% and 61.26% of Cattle, Buffalo, Sheep and Goat, respectively). The Indian livestock inventory needs timely identification, characterization, documentation, evaluation and conservation on priority level so as to ensure sustainable livestock production for prolonged times. National Bureau of Animal Genetic Resources (NBAGR) is designated as nodal agency by Indian Council of Agricultural Research (ICAR) for the purpose of characterization and documentation of AnGR in India at the national level. The effective management of AnGR at national and international

level needs qualified, adequately updated and skilled manpower. The manpower should be optimally equipped with knowledge and skills regarding basic principles of AGB along with the latest and advanced developments. Skilled manpower is produced in teaching institutions where teachers try to stamp the basics of AGB along with polishing the sharp young minds.

Genetics and breeding courses are taught in more than 41 State Agricultural Universities (SAUs)/colleges at undergraduate, postgraduate and/or doctorate levels. Most of these institutions follow the curricula recommended by the Veterinary Council of India (VCI). AGB teaching mainly consists of knowledge in three fields' viz., conventional animal breeding, application of molecular genetics in livestock production and reproduction of “superior” genetic material. On one hand, teaching molecular genetics is directed at the understanding of basic principles of genetic variation and inheritance. Whereas teaching animal breeding aims to make pupils understand the application part of animal genetics for livestock improvement and animal/human welfare. In conventional animal breeding, the concepts of selection and mating systems are introduced. Though stress is always given to balance the teaching in these fields, AGB teaching currently has been skewed either to Animal Breeding or to Molecular Genetics, especially in the last few decades. It culminates into incomplete knowledge of both the fields. Other main accessory fields of AGB include Cytogenetics and Conservation Genetics. Recently, many fields related to applied aspects of genetics have arisen in Nutrition (Nutrigenetics and Nutrigenomics), Pharmacology (Pharmacogenetics), Reproduction (Velogenetics) and Immunology (Immunogenetics). Various other applied branches continue to emerge stressing the importance of AGB in other subjects of veterinary and animal sciences too.

#### **Present curricula for AGB teaching**

The teaching of AGB in India is based on the curriculum recommended from time to time by the VCI through its Minimum Standards of Veterinary Education (MSVE) regulations. The present curricula cover teaching at undergraduate (UG), postgraduate (PG) and doctoral (Ph.D.) level and are briefly discussed here.

#### ***Present curriculum for undergraduate program***

As per the MSVE 2016 regulations for Bachelor of

Veterinary Science and Animal Husbandry (B.V.Sc & A.H), AGB is taught as a course of 3+1 credit hours divided into three major units viz., Biostatistics and Computer Application; Principles of Animal Genetics and Population Genetics; and Principles of Animal Breeding.

The unit on biostatistics deals with topics of basic statistics and computer knowledge. Basic statistics' teaching includes classification, tabulation and representation of data; measures of central tendency and dispersion; moments, skewness and kurtosis; correlation and regression; probability distributions: methods of sampling; tests of hypothesis; designs of experiment; analysis of variance (ANOVA); and nonparametric tests. The computer applications subunit includes topics such as introduction to computer languages; database management; MS-Office and its components (MS-Word, Excel, PowerPoint and Access); data entry, saving and analysis of biological data using MS-Excel; concepts of computer networks, internet and e-mail.

Principles of animal genetics unit covers topics such as Mitosis and Meiosis; chromosome numbers and types in livestock and poultry; overview of Mendelian principles; modified Mendelian inheritance; pleiotropy, penetrance and expressivity; multiple allelism; lethals; sex-linked, sex limited and sex influenced inheritance; sex determination; linkage; crossing over and construction of linkage map; mutation; demonstration of karyotyping in farm animals; chromosomal aberrations; cytogenetics; extra-chromosomal inheritance; nucleic acids-structure and function; concept of gene; DNA and its replication; and introduction to molecular techniques.

Population Genetics unit focuses on areas pertaining to individual vs population; Genetic structure of population; gene and genotypic frequency; Hardy-Weinberg law and its applications, forces changing gene and genotypic frequencies; quantitative vs. qualitative genetics; concept of average effect and breeding value; components of variance; interaction between genotype and environment; heritability and repeatability; genetic and phenotypic correlations.

The unit on Principles of Animal Breeding includes classification of breeds; economic characters of livestock and poultry and their importance; selection, types of selection, response to selection and factors affecting it; bases of selection; method of selection; computation of selection differential and intensity of

selection, generation interval, expected genetic gain; computation of selection index; computation of sire indices; classification of mating systems; inbreeding coefficient and coefficient of relationship; genetic and phenotypic consequences of inbreeding, inbreeding depression and application of inbreeding; genetic and phenotypic consequences of outbreeding, application of outbreeding, systems of utilization of heterosis; selection for combining ability; breeding strategies for the improvement of dairy cattle and buffalo; breeding strategies for the improvement of sheep, goat, swine and poultry; sire evaluation; open nucleus breeding system (ONBS); development of new breeds or strains; current livestock and poultry breeding policies and programmes in the state and country; methods of conservation- livestock and poultry conservation programmes in the state and country; application of reproductive and biotechnological tools for genetic improvement of livestock and poultry; breeding for disease resistance; breeding of pet, zoo and wild animals; classification of dog and cat breeds; pedigree sheet, selection of breeds and major breed traits; breeding management of dogs and cats; common pet birds seen in India and their breeding management; population dynamics and effective population size of wild animals in captivity/ zoo/ natural habitats; planned breeding of wild animals; controlled breeding and assisted reproduction; and breeding for conservation of wild animals.

#### ***Present curricula for the post graduate and doctoral program***

As per the MSVE 2009 regulations for Master of Veterinary Science (MVSc), the course content for AGB is divided into 10 courses, namely, Animal Cytogenetics and Immunogenetics, Molecular Genetics in Animal Breeding, Population and Quantitative Genetics in Animal Breeding, Selection Methods and Breeding Systems, Biometrical Techniques in Animal Breeding, Conservation of Animal Genetic Resources, Cattle and Buffalo Breeding, Small Farm Animal Breeding (Sheep, Goat, Swine and Rabbit) and Poultry Breeding, Laboratory Animal Breeding. Similarly, the curricula for the doctoral program in AGB consists of seven courses, namely, Recent Advances in Animal Genetics, Recent Trends in Animal Breeding, Advances in Biometrical Genetics, Advances in Selection Methodology, Bioinformatics in Animal Genetics and Breeding, Advances in Molecular Cytogenetics and Utilization of Non-Additive Genetic Variance in Farm Animals as per the MSVE 2009 regulations. However, little variation exists in the

curricula between the two deemed Universities (ICAR-Indian Veterinary Research Institute and ICAR-National Dairy Research Institute) when compared to SAUs and other institutions.

### Online Tools for teaching AGB in India

Under the aegis of National Agricultural Innovation Project (NAIP), the Indian Council of Agricultural Research (ICAR) in collaboration with Tamil Nadu Veterinary and Animal Sciences University (TANUVAS), Chennai has created an interactive multimedia *e-Learning* module for the B.V.Sc & A.H courses as per the VCI syllabus. This *e-learning* portal on agricultural education is an easily accessible and shareable repository of learning resources for Veterinary and Animal Sciences in India available at <https://ecourses.icar.gov.in/>. Though, other Universities (CAU, Assam; SKUAST-K, J&K; CSKPHKV, Himachal Pradesh) have also taken some initiatives but their material is mostly limited to the bona fide students of the University.

### Challenges in AGB teaching

AGB is considered a challenging subject by the students. Undergraduate students, mostly from biology background, develop a kind of fear towards this discipline. This may be mainly due to lack of knowledge in elementary mathematics and statistics. Statistical background and support is also inadequate at PG and Ph.D. level. The teaching of statistical portion of AGB through PowerPoint presentations further complicates the understanding. In the present VCI curriculum, the time allocated for teaching AGB to UG students has been curtailed to an inadequate level, keeping in view the mathematical / statistical derivations. Animal breeding courses, offered without completion of prerequisite courses like mathematics/statistics/reproduction/LPM further worsens the problem.

The non-availability of *Tribolium* and *Drosophila* experimentation facilities in most of the colleges/universities, which were routinely available about 15-20 years back, has taken away the cushion of easy understanding of concepts through experimentation. They were helpful for understanding complex concepts of quantitative genetics. Availability of livestock farm facilities for each species like cattle, buffalo, sheep, goat, pig is palpably missing in most of the colleges. In addition, hands-on experience in collecting huge phenomic data from the livestock farms and its statistical analysis using advanced tools is not given

place in the curricula. The computational and wet laboratory facilities are not available at most of the colleges that add to the problems.

Teachers frequently rely on PowerPoint presentations to deliver lectures without using chalk and board. It compromises with effective explanation of concepts at a slow and understandable pace, especially for mathematical/statistical calculations. The online study material for undergraduate courses available at “e-Learning portal on agricultural education” is not updated as per MSVE 2016. Non-availability of same study material nationwide is causing lack of uniformity in the reference material across the country. It has also been observed that this portal does not operate on many occasions.

There is a dearth of online portals containing study material and practical manuals for postgraduate students. Furthermore, there is little exposure for postgraduate students on “Livestock Farm Practices” in order to make them learn and understand routine farm activities. State-of-the-art farms need to be established at public and industry level so that students are adequately sensitized to best practices of livestock development and management. An acute shortage of skilled manpower is felt at ground level that ultimately hampers the decision support systems *viz-a-viz* germplasm improvement decisions. A skill development course at postgraduate level as per the demands in the livestock industry is missing which will enhance the employability of the postgraduates.

PG students are hardly exposed to adequate levels of bioinformatics learning. A closer look into bioinformatics course in the doctoral curriculum in AGB reveals that the course restricts itself to basic concepts of bioinformatics such as the study of protein and genome databases, sequence analysis, sequence alignments and phylogeny. Basic knowledge of computer languages like R, C++, FORTRAN and Java are also not included in the syllabus, which are highly essential even at the undergraduate level to inculcate the programming skills among students.

### Possible solutions

There is huge scope for improvement in AGB teaching at UG, PG and Ph.D. levels. Firstly, curricula have to be designed in such a way so that interest could be created among the students and any apprehension could be removed from their mind. One way of making subject interesting is by narrating inspiring anecdotes on famous personalities who have contributed to the

subject. Other ways include stressing on teaching concepts (not simply facts), making skills as a part of teaching, rewarding the skills and being innovative. Formulation and implementation of active-learning instruction strategies are needed where environment should be conducive for lively interaction between teachers and students. Another possible solution includes setting of learning goals prior to the start of a course and assessing and taking feedback at the end (Smith and Wood, 2016). Prerequisite concepts (elementary mathematics and statistics) to understand genetics and breeding should be taught prior to the start of the course. Therefore, the time allocated for teaching AGB to undergraduate students has to be increased in view of mathematical/statistical derivations. Moreover, learning through Vedic and ALOHA tricks may prove helpful for improved statistical learning besides generating interest in students for statistical genetics. AGB Societies should play their active role in organizing the quizzes and other related activities at the national and international level to generate the interest in students for the subject.

Laboratory practical exercises on *Tribolium* and *Drosophila* should be included in the curricula in order to practically demonstrate the important concepts of genetics in the laboratory. Livestock farm facilities for each species like cattle, buffalo, sheep, goat, pig; which are essential for understanding the genetic mechanisms underlying quantitative traits should be made available in all the colleges. In addition, hands-on experience in collecting huge phenomic data from the livestock farms and its statistical analysis using advanced tools must be included in the curricula. Advance data analysis techniques should also be included in the syllabus. These may include variance component analysis, multivariate analysis, non-linear modeling, Bayesian statistics, RR-BLUP, LASSO, G-BLUP, single step genomic prediction and others. In order to sensitize students about efficient phenomic data recording, exposure visits should also be organized to state of the art farms under the control of government as well as the industry covering all the livestock species. The computational and wet laboratory facilities at each college should be strengthened. It will help students to get exposed with the latest software tools for understanding the molecular mechanisms underlying important traits in domestic animals.

Updated online study material for undergraduate courses and an online portal containing study material and practical manuals for postgraduate students should

be created. Since the curriculum is same for the entire nation, providing same study material nationwide through online study portals will create uniformity in the reference material across the country. A compulsory course on "Livestock Farm Practices" in line with undergraduate students should be included in 1<sup>st</sup> year for postgraduate students so that they become aware about the routine farm activities. A skill development course should be designed at postgraduate level using specialized techniques of AGB for fulfilling the demand of manpower in the industry.

In the present era molecular genetics (including genomic selection and genome-wide association studies), animal breeding or any other branch of AGB involve huge data generation and analysis. Therefore, AGB teaching should be focused towards adequate learning of data generation, analysis and interpretation. Statistics teaching should involve real farm data-based examples. The content of the bioinformatics course in the curriculum of doctoral program of AGB should encompass basic knowledge of computer languages like R, C++, FORTRAN and Java in order to inculcate the programming skills. New languages and softwares (MATLAB, WeKa, ADMIXTURE, WOMBAT, etc.) are being continuously developed covering different applied aspects of AGB. There is an utmost need to update knowledge regarding these languages and softwares for both the teachers and students.

Teachers should have critical knowledge of principles and concepts of genetics. Hence, they must be screened at the initial level, thoroughly. Involvement of the students at the time of screening may add in identification of the teacher with good communication skills and clarity of concepts. Furthermore, there must be a balance in proportion of teachers having expertise in Animal Breeding and Molecular Genetics so that all the aspects of AGB are properly covered. A sufficient number of teachers need to be regularly trained on the topics of recent developments through national and international training programs.

PowerPoint-based teaching is an efficient tool for dissemination of information. However, all the lectures, especially those which include mathematical/statistical derivations and calculations should not be delivered through this technique. The demerits of PowerPoint teaching include limited interaction with students, less control over speed of information flow and/or unmanaged order of slides (Xingeng and Jianxiang, 2012). Board based teaching is highly

recommended for such courses. Furthermore, more emphasis should be given for teaching through videos and animations to understand complex concepts of genetics. Innovative solutions include use of new technologies like information kiosks, artificial intelligence, machine learning and neural networking. These may be useful for real-time and reliable data recording with easy retrieval and timely analysis along with application in behavior related studies. Such studies, presently, are being focused towards animal behavior, estimation of breeding values and developing prediction equations (Shahinfar et al. 2012; Valletta et al. 2017).

Concept inventories are used to measure the learning capacity of students and conveying efficiency of the teachers over an entire course. These are typically given to students at the beginning and at the end of the course. They are designed to test the conceptual difficulties, to measure conceptual mastery over time and also to help the faculty to identify areas, where improvements in their instruction are needed (Smith and Wood 2016). Some of the published concept inventories in genetics are Genetics Literacy Assessment (Bowling et al. 2008), Genetics Concept Assessment (Smith et al. 2008), Genetics Diagnostic (Tsui and Treagust 2009), Meiosis Concept Inventory (Kalas et al. 2013), Genetic Drift Inventory (Price et al. 2014), Molecular Biology Capstone Assessment (Couch et al. 2015), Central Dogma Concept Inventory (Newman et al. 2016) and Lac Operon Concept Inventory (Stefanski et al. 2016). There is an urgent need to develop more and more concept inventories for all the important concepts of AGB and to use them in Indian Universities.

### Declaration

The authors declare no conflict of interest.

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