

# PRINCIPLES OF GENETICS AND CYTOGENETICS

(As per ICAR 6<sup>th</sup> Dean Committee) B.Sc. (Horticulture), 1<sup>st</sup> Semester

This book has been designed to cover the course of graduate and post-graduate levels of various Indian agricultural and general universities. It also covers the syllabus of Agricultural Research Services Examination and National Eligibility Test conducted by the Indian Council of Agricultural Research, New Delhi. This book will be helpful to the students (UG, PG & Ph.D.), Teachers, Scientists, Researchers those who are engaged in working in the field of Genetics & Plants Breeding. This book will be also helpful for other competitive exams like Agricultural Research Services (ARS) conducted by ASRB, New Delhi & Other Civil Services exams & IBPS exams for Agriculture Officers. Especially this book is designed to fulfill the course curriculum of B.Sc.(Horticulture), 1<sup>st</sup> semester students as per ICAR 6th Dean Committee Syllabus.

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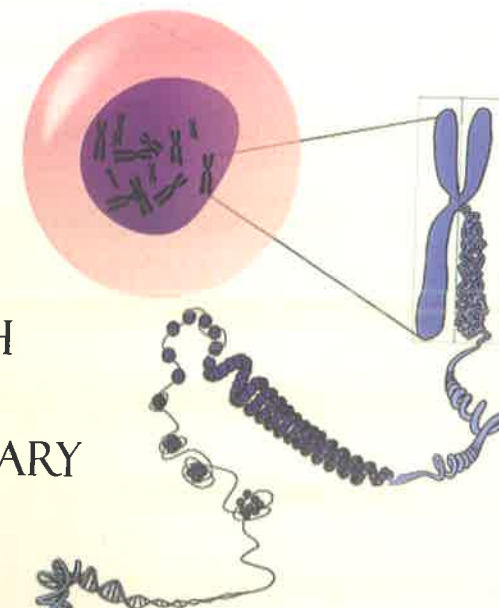
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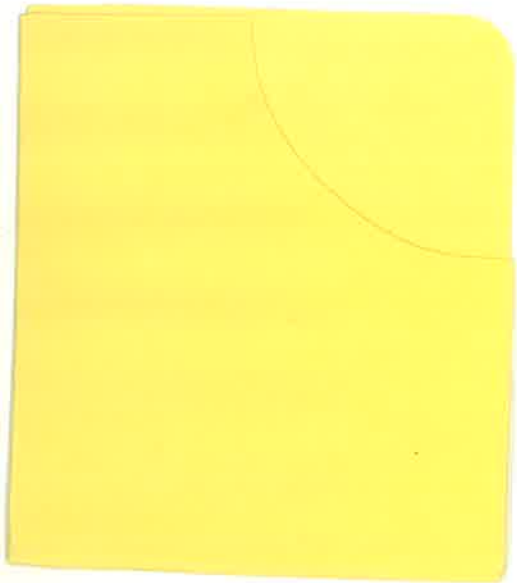
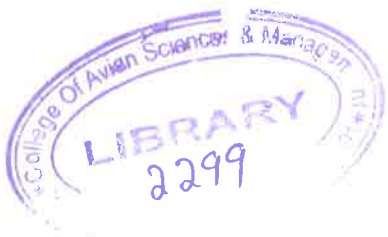
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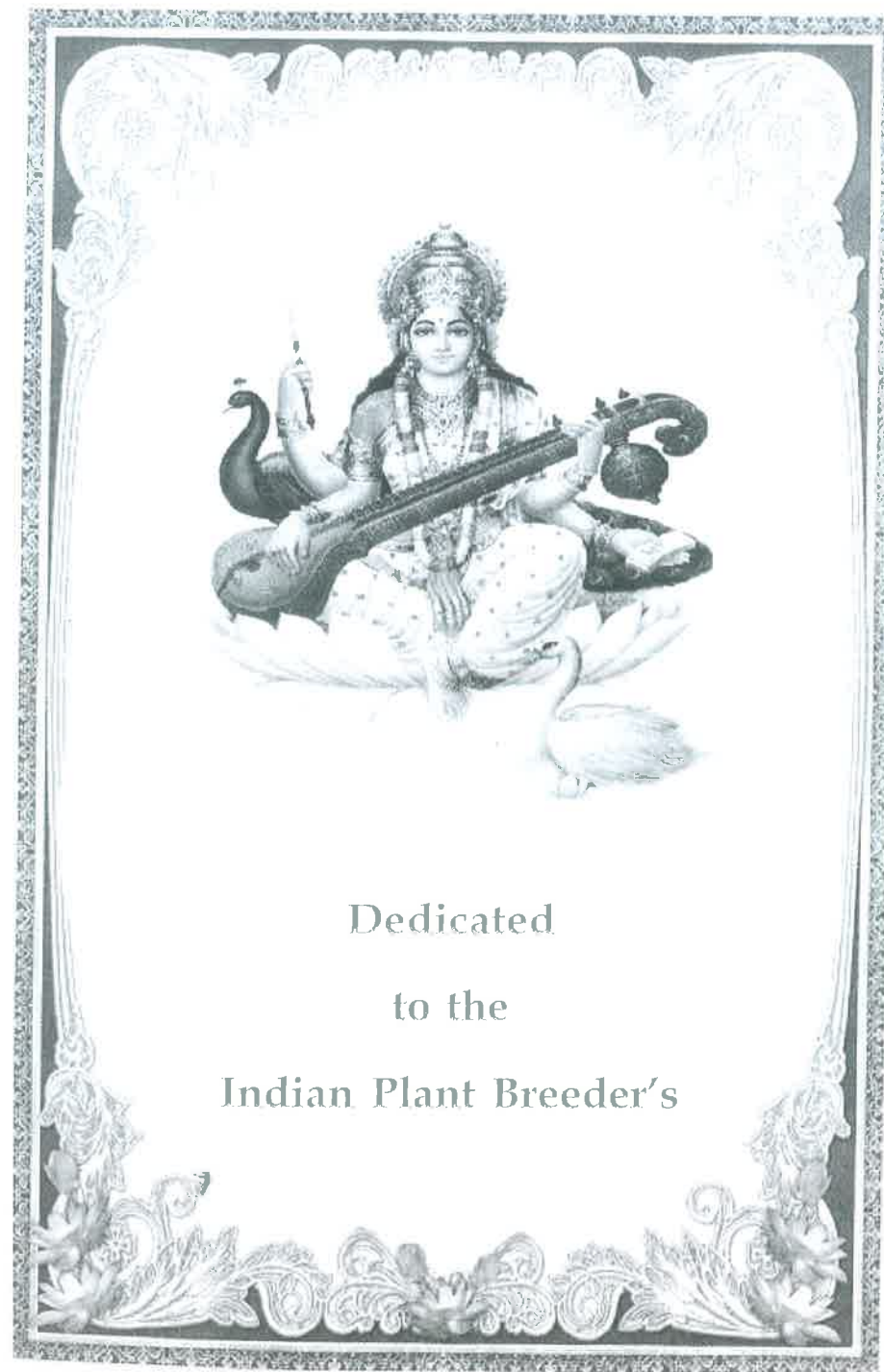
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Composed, Designed & Printed in India



Dedicated

to the

Indian Plant Breeder's

## About the Authors

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**Dr. Mahak Singh** has over 31 years of research, teaching experience in Plant Breeding and Genetics in various capacities. He has published more than 188 research papers and articles in reputed scientific journals and magazine. He has participated and presented research papers in various National and International Conferences, Seminars and Symposia. He has contributed ten varieties of Rapeseed-mustard, namely, **Urvashi (RK 9501)**, **Basanti (RK 8501)**, **Kanti (RK 9807)**, **Maya (RK 9902)**, **Ashirwad (RK 01-3)**, **Pitambari (RKYS 05-2)**, **Tapeshwari (TK 06-1)**, **Azad Chetna (TKM-14-2)**, **Azad Mahak (KMR (E) 15-2)** and **Surekha (KMR-16-2)**. He was Incharge, AICRP Groundnut Mainpuri and Incharge, AICRP Linseed, Kanpur. He is an author of Seventeen books viz., **"Seed Production Technology of Oilseed Crops"**, **"Hand Book of Science and Agriculture"**, **"Atlas Oilseed Crops"**, **"Production Technology of Oilseed Crops"**, **"Breeding Oilseed Crops"**, **"Principles of Seed Technology"**, **Beej Prodhogiki ke Sidhant (Hindi)**, **"Agricultural Research Policy in India: pre & post-covid-19 Pandemic era"**, **"Agricultural Research Strategies in India"**, **"Agricultural Research Systems in India : pre & post-covid-19 Pandemic era"**, **"Research Status of Agricultural Sciences in India : pre & post-covid-19 pandemic era"**, **"Research trends in Agricultural Sciences: Pre & post-covid-19 Pandemic era"**, **"Crop Improvement"**, **"Biometrical Analysis in Yellow Sarson"**, **"Genetic analysis in Indian mustard"**, **"Research Trends in Seed Production Technology in Oilseeds Crops"**, and **"Rapeseed & Mustard"**.

Dr. Mahak Singh is expert in Public Service Commission and Higher Education in different states and member of several scientific societies and referee of different Journals. He remained member of Board of studies in Agricultural Botany in Meerut University, Meerut for three years (From 2008 to 2012), member of Board of studies in Agricultural graduate and Post-graduate in State University, Allahabad (U.P.) From 2017 to till date, Member Board of Studies and Research Advisory in Agricultural Botany Department in B.H.U. Varanasi (U.P.) from 2017 to till date and member of Board of Studies in Agricultural Graduate and Post-graduate in Dr. Ram Manohar Lohia, Awadh University, Faizabad (From 2009 to till date). Member of the Education Council at Veer Bahdur Singh Purvanchal University, Jaunpur-222002 (U.P.) (From 28.09.2020 to till date). Presently he is Head, Department of Genetics & Plant Breeding and Incharge AICRP (Rapeseed-mustard), then Groundnut, Linseed and Castor

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**Dr. V. V. Singh** did his Ph.D. in Plant Breeding & Genetics from Rajasthan Agricultural University, Bikaner. Presently he is working as Principal Scientist (Plant Breeding) at ICAR-Directorate of Rapeseed-Mustard Research Bharatpur (Raj). Dr. Singh has a bright academic career. He has been awarded University Merit Scholarship and Gold Medal (for M.Sc. (Ag)). Prior to joining ICAR in 2006, he served SKN College of Agriculture, Jobner as Assistant Professor for more than ten years and taught several under-graduate and post-graduate courses in Plant Breeding and Genetics. Dr. Singh has successfully guided 08 M.Sc. students for their thesis. His research interest includes genetic enhancement of Indian mustard for biotic and abiotic stresses, marker assisted selection and quality improvement. He has developed/contributed in development of 07 varieties and 19 genetic stocks of rapeseed-mustard. He has published more than 80 research papers, 59 abstracts/proceeding papers, 08 book chapters, 12 popular articles, 01 book and 20 technical bulletin/manuals/folders. He is a life time member of more than 04 professional societies and has been editor of NAAS rated journals. Dr. Singh has been designated fellow of prestigious Indian Society of Genetics and Plant Breeding, New Delhi and has received 03 awards from similar professional societies.



**Dr. A. K. Choudhary** has been heading the Division of Crop Research at the ICAR Research Complex for Eastern Region, Patna (Bihar). Basically Plant Breeder by profession, Dr. Choudhary has a bright academic career; he ranked first in M.Sc. (Ag) and Ph.D. while studying at RAU, Pusa, Samastipur (Bihar). He has been awarded ICAR Junior Research Fellowship (during M.Sc.), CSIR Senior Research Fellowship (during Ph.D.) and Gold Medal (for M.Sc.). He has taught several under-graduate and post-graduate courses in Plant Breeding and Genetics, and guided three M.Sc. students (one each in fenugreek, cluster bean and Indian mustard), while serving at SKN College of Agriculture, Jobner (Rajasthan) during 1996-2002 as an Assistant Professor. Dr. Choudhary has been exclusively engaged in research work since the last 18.5 years. He has developed a number of novel genotypes in fenugreek, cluster bean, pigeonpea, chickpea, lentil, grass pea and field pea; many of which are already registered with NBPGR, New Delhi as donors or released as varieties. During his research career, he has generated several first hand genetic information which got published in the world's renowned journals, such as *Plant Breeding*, *Breeding Science*, *Indian Journal of Plant Breeding and Genetics*, *Physiology and Molecular*

*Biology of Plants*, *The Crop Journal*, *Field Crops Research*, *Crop and Pasture Science*, *Biotechnology Advances*, *Planta*, *Plos One*, *International Journal of Molecular Sciences*, and the like. Thus far, Dr. Choudhary has published more than 80 research articles, 10 proceedings paper, 20 book chapters, 20 popular articles, 02 books, 01 technical bulletin and several folders and leaflets. He has been involved in editing journals like *Journals of Food Legumes*, *Current Advances in Agricultural Science* and *SABRAO Journal of Breeding and Genetics*. He is a life time member of more than 05 professional societies. Dr. Choudhary has been designated fellow of prestigious societies like ISGPB, New Delhi and ISPRD, Kanpur, and has received 08 awards from similar professional societies.



**Dr. Amit Tomar** (b. 1987) hails from an agricultural family of Western Uttar Pradesh (Village-Hathchhoya, Tehsil- Unn, District- Shamli). He is Graduate in B.Sc. Agriculture and has obtained his Master and Doctorate degrees in Genetics & Plant Breeding from Chandra Shekhar Azad University of Agriculture & Technology, Kanpur. He has throughout a brilliant academic record. He has been awarded the Gold Medal in M. Sc. (Ag) degree. He is an author of more than 12 books viz., "**Breeding Oilseed Crops**" Published from **Agro India Publication, Allahabad**, "**Plant Science At A Glance**" Published from **Balaji Publication, New Delhi** and "**Competitive Plant Breeding**" Published from **Kushal Publication & Distributers, Varanasi**, "**Seed Technology**" published from **Kushal Publication & Distributions, Varanasi**, "**Genetic Analysis for Seed Yield and its Contributing Traits in Indian Mustard (*Brassica juncea* L. Czern & Coss)**" and "**Research trends in seed production technology of oilseed crops**" Published from "**Lambert Publication Academy, Germany, etc.** He is a member of several scientific societies and published more than 100 research papers and 25 review papers and more than 25 popular articles in reputed scientific journals/magazines and he has passed National Eligibility Test (three times) in Genetics & Plant Breeding, conducted by Agricultural Scientist Recruitment Board (ASRB). He has qualified the ARS exam (pre & mains three times). He awarded Inspire Fellowship from Department of Science & Technology, New Delhi during his Ph.D. programme. Presently he is working as a **Teaching/Research Associate** in Genetics & Plant Breeding at **Rani Lakshmi Bai Central Agricultural University, Jhansi, U.P., India.**

## *Preface*

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The book Principles of Genetics and Cytogenetics is intended to serve as a text book for under-graduate students studying in various state agricultural universities (SAUs) and Central Agricultural Universities (CAUs) of India. This book covers basic topics related to heredity and genetics, cytogenetics and molecular genetics. The book is sub-divided into twenty two chapters. History of genetics, basic concepts on pre-Mendelian, Mendelian and post-Mendelian genetic analyses are unique features of this book. Topics on gene action, cytoplasmic inheritance, multiple factor hypothesis, linkage and crossing over and fine structure of gene have been fully elaborated with illustrations and experiments. This will let students grasp the concepts easily and rapidly. The chapters on gene regulation, genetic material, translation and transcription, chromosomal aberrations and mutations comprise fully updated information as per syllabus prescribed for under-graduate students of Indian Universities. At the end of each chapter questions are given for doing exercise and practice by the students.

Authors hope and trust the book will serve the purpose of students, teachers and researchers alike. We are highly grateful to all the colleagues from ICAR institutes, SAUs and CAUs who have directly or indirectly helped in the preparation of the manuscript.

Authors do not claim that the book is free from shortcomings and mistakes. Authors welcome critical comments and suggestions from students and readers to bring about further improvement in this book.

01 March, 2021  
Kanpur

**Authors**

## *Contents*

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<i>About the Authors</i> .....	<i>vii</i>
<i>Preface</i> .....	<i>xi</i>
1. History, Nature and Scope of Genetics .....	1
2. Mendel's Laws of Inheritance .....	11
3. Ultra Structure of Cell and Cell Organelles .....	35
4. Cell Division: Mitosis & Meiosis .....	59
5. Types of Gene Action .....	75
6. Multiple Alleles .....	85
7. Linkage and Crossing Over .....	93
8. Chromosome Structure and Morphology .....	113
9. Chromosomal Aberrations .....	133
10. Mutations .....	159
11. Quantitative and Qualitative Traits .....	173
12. Multiple Factors Hypothesis .....	183
13. Genetic Materials (DNA & RNA): Structures & Functions ...	189
14. Protein Synthesis (Transcription & Translation) .....	217
15. Fine Structure of Gene .....	241



16. Regulation of Gene Expression .....	257
17. Cytoplasmic Inheritance .....	265
18. Probability and Chi-Square-Test .....	273
19. Sex Determination: Genetics Disorders .....	297
20. Syllabus .....	309
21. Practical Exercise .....	311
22. Question Bank.....	363
23. Multiple Choice Questions on Cytogenetics .....	381
References .....	423

Chapter 1

## History, Nature and Scope of Genetics

The **history of genetics** started with the work of the Augustinian friar Gregor Johann Mendel, who published his work on pea (*Pisum sativum* L.) in 1866. His contributions are known as Mendelian Inheritance. However, related works started centuries before, and continued thereafter to discover the physical basis of Mendel's work.

The year 1900 marked the "re-discovery of Mendel's work" by Hugo de Vries (Netherlands), Carl Correns (Germany) and Erich von Tschermak (Austria). By the year 1915, the application of basic principles of Mendelian genetics started in a wide variety of organisms, the most notable being the fruit fly (*Drosophila melanogaster* L.). Led by Thomas Hunt Morgan and his fellow "drosophilists", geneticists developed the Mendelian model, which was widely accepted by the year 1925. Parallel to these works, mathematicians developed the statistical framework of population genetics, bringing genetic explanations to the study of evolution.

With the basic patterns and physical basis of genetic inheritance established, many biologists turned towards investigating the biochemical nature of the gene. In the 1940s, experiments revealed that DNA is the genetic material, and a gene is a short segment of DNA. This was followed by a landmark discovery, the double helical structure of DNA in 1953. In continuation, semi-conservative mode of replication was also deciphered both in pro- and eukaryotes.

In the following years, chemists developed techniques for sequencing both nucleic acids and proteins, while others worked out the relationship between the two forms of biological molecules: the genetic code. The regulation of gene expression became a central issue in the 1960s; by 1970s gene expression and manipulation through genetic engineering could get established. In the last decade of the 20th century, many biologists focused on projects related to sequencing of entire genomes.