

Research Methodology in Plant Science



SCIENTIFIC
PUBLISHERS

P. Suresh Narayana
D. Varalakshmi
T. Pullaiah

RESEARCH METHODOLOGY IN PLANT SCIENCE

About the Authors



P. Suresh Narayana obtained his M. Sc. degree (1971) in Botany from Sri Venkateswara University. Later, he joined the Department of Botany, S. S. B. N. Junior College, Anantapur (1971) as a Junior Lecturer and served the institution for more than 37 years. He rose to become the Principal of the same institution (2006). He took active interest in popularizing Botany, among College and High School students. Many a time he participated in District Science Fairs and Children's Science Congresses as an adjudicator and encouraged the students to develop the scientific temper. He participated in several National Symposia in Botany, Environmental Sciences and Biotechnology. He gave many radio talks on plants, environment and biotechnology over All India Radio. He actively participates in the social activities among the elite of Anantapur. He is a member of a few scientific societies of India. He also organized a couple of symposia in Plant Sciences and Biotechnology, Quiz programmes and elocution and essay writing competitions. During his tenure as Principal, he established the NSS unit in the college and conducted many programmes such as 'Clean and Green', 'Planting' and 'Environmental Awareness'. He conducted many botanical tours and accompanied students for collections. His hobbies include reading, correspondence, photography and collection of books and stamps. He is also an Executive Member of a few local educational institutions and organizations. He retired from active service in June 2008. His recent publications include: *Eminent Indian Botanists – Past and Present – (Biographies and Contributions)*, *Text Book of Pharmacognosy – Volume I, II and III and Research Methodology in Zoology* etc.



D. Varalakshmi obtained her M. Sc., degree (1972) in Botany from Sri Venkateswara University, Tirupathi, and M. Phil., degree from Sri Krishnadevaraya University, Anantapur (1986). She joined the Department of Botany, Government Junior College, Pendurthi, Visakhapatnam (1975) as Junior Lecturer and later served in different Government Junior Colleges of Visakhapatnam, Kurnool and Anantapur districts for 18 years. She was promoted as a Lecturer and joined the Department of Botany, Government Degree College, Anantapur (1993). She was a Lecturer in the Department of Biotechnology since its inception (1998) in the college and was kept in-charge of the Department in the same institution (2001) where she established a full working laboratory and library in the department which was a model for the establishment of biotech laboratories in other colleges. She took active interest in the popularization of Botany among students and many

a time participated in the District Science Fairs and Children's Science Congresses as an adjudicator. She participated in several National Symposia in Botany, Biotechnology and Environmental Sciences. She also gave radio talks on different topics of botany and biotechnology over All India Radio. She actively participated in the social activities among the elite of Anantapur. She organized a couple of Regional and National Symposia in Biotechnology and Quiz programmes. She conducted many botanical tours and educational tours in Biotechnology and accompanied the students for collections. Her hobbies include reading and collection of books. She retired from active service in August 2008. She is the Co-author of 5 publications: *A Text Book of Pharmacognosy – Volume I, II and III and Research Methodology in Zoology* etc.



Prof. T. Pullaiah obtained his M. Sc. (1973) and Ph. D. degrees in Botany from Andhra University. He was a Post-doctoral Fellow at Moscow State University, Russia, during 1976-1978. He travelled widely in Europe and visited Universities and Botanic Gardens in about 17 countries. He joined Sri Krishnadevaraya University as Lecturer (1979) and became Professor (1993). He held several positions in the University as Dean, Faculty of Life Sciences; Head, Department of Botany; Chairman, Board of Studies in Botany; Head, Department of Sericulture; Co-ordinator and Chairman, Board of Studies in Biotechnology; Principal, Sri Krishnadevaraya University College. He retired from active service in 2011 and was selected by UGC as UGC-BSR Faculty Fellow in the Department of Botany, Sri Krishnadevaraya University. He has published 75 books, 330 research papers and 35 popular articles. His books include: *Global Biodiversity* (4 volumes, Apple Academic

press), *Ethnobotany of India* (5 volumes Apple Academic press), *Red Sanders: Silviculture and Conservation* (Springer), *Monograph on Brachystelma and Ceropegia in India* (CRC Press), *Flora of Andhra Pradesh* (5 volumes), *Flora of Eastern Ghats* (7 volumes), *Encyclopaedia of World Medicinal Plants* (7 volumes), *Biodiversity in India* (8 volumes), *Taxonomy of Angiosperms* (presently in 4th edition), *Plant Development*, *Eminent Indian Botanists – Past and Present – (Biographies and Contributions)*, *Text Book of Pharmacognosy – Volume I, II and III* etc. He was the Principal-Investigator of 20 major Research Projects totalling more than three Crores of Rupees funded by DBT, DST, CSIR, UGC, BSI, WWF, GCC etc. Under his guidance, 54 students obtained their Ph.D. degrees and 34 students their M.Phil. Degrees. He is the recipient of Best Teacher Award from the Government of Andhra Pradesh, Prof. P. Maheshwari Gold Medal of the Indian Botanical Society and Prof. Y.D. Tiagi Gold Medal of the Indian Association for Angiosperm Taxonomy. He was President of Indian Association for Angiosperm Taxonomy (2013) and President of the Indian Botanical Society (2014).

RESEARCH METHODOLOGY IN PLANT SCIENCE

2nd Edition

P. Suresh Narayana

Principal (Rtd.).
S.S.B.N. Junior College
Anantapur 515001, A. P.

D. Varalakshmi

Lecturer in Botany (Rtd.).
Government Degree College
Anantapur 515001, A. P.

Prof. T. Pullaiah

Professor (Rtd.).
Department of Botany
Sri Krishnadevaraya University
Anantapur 515003, A. P.



Published by

SCIENTIFIC PUBLISHERS (INDIA)

5 A, New Pali Road, P.O. Box 91

Jodhpur 342 001 (India)

E-mail: info@scientificpub.com

Website: www.scientificpub.com

© 2020, Authors

All rights reserved. No part of this publication or the information contained herein may be reproduced, adapted, abridged, translated, stored in a retrieval system, computer system, photographic or other systems or transmitted in any form or by any means, electronic, mechanical, by photocopying, recording or otherwise, without written prior permission from the publisher.

Disclaimer: Whereas every effort has been made to avoid errors and omissions, this publication is being sold on the understanding that neither the editors (or authors) nor the publishers nor the printers would be liable in any manner to any person either for an error or for an omission in this publication, or for any action to be taken on the basis of this work. Any inadvertent discrepancy noted may be brought to the attention of the publisher, for rectifying it in future editions, if published.

Trademark Notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation without intent to infringe.

ISBN : 978-81-7233-992-0 [HB]

978-81-7233-997-5 [PB]

Visit the Scientific Publishers (India) website at

<http://www.scientificpub.com>

Printed in India

PREFACE

For many years of observation during the last decade, it is our common observation that our students who approached us for the necessary suggestions about their future after post-graduation, and those who wish to carry out research in plant science, expressed that they find it very difficult to procure relevant material to take up their M. Phil, or pre-Ph. D, examination as the different chapters of research methodology cannot be located all at one place, and it was very difficult to procure the same. And some of them have also requested us to prepare a source book on research methodology in plant science which can be of use to the researchers and teachers where all the topics are at one place. Thus, the impetus for the publication of this book on '*Research Methodology in Plant Science*' began with an effort to provide a source book on research methodology wherein all the topics lie at one place for the benefit of the students.

This publication is a practical, down-to-earth text book for those people who wish to carry out research and also who want to appear for their examinations for M. Phil, and Pre Ph.D., as no book exclusively dealing with *Research Methodology in Plant Science* is available in the market. This book is designed to provide M.Phil. and Ph.D, students, with a concise introduction to conducting research not only in organizations but also in Universities. The main aim of the book is to impart knowledge for making the appropriate methodological choice and to provide readers a practical guide to design and execute a research problem. The book is aimed at those who are new to research and have no prior knowledge of the issues covered herein. It will also provide more about the research methods that are available to those people who have already conducted some research and interested in finding out more. This book is more than a text on research methods in plant science, and it is an introduction to the theoretical concepts as well as the descriptive and analytical research methods that are used by different disciplines associated with research in plant science.

These days' people, students and teachers frequently talk of research, both in the academic institutions as well as outside. Many research studies are undertaken and accomplished year after year, but in most cases, very little attention has been paid to an important dimension related to research, that of research methodology. Thus, a great deal tends to be futile as the significance lies in its quality and not in its quantity. Therefore, an urgent need is to pay due attention to designing and adhering to appropriate methodology for improving the quality of research. The methodology may always differ from problem to problem, yet the basic approach towards research remains the same.

Keeping all these points in view, the present book has been written with three clear objectives, namely, to enable the students as well as the researchers in plant science, to prepare well and to be successful in the M.Phil. and Pre Ph.D. examination, irrespective of their branch/field; when once they get into research, in

the development of an appropriate methodology for their research studies; and also to make them familiar with an art of using different methods and techniques. It is our ambition that this humble effort in taking out this book will definitely assist the students and the researchers in the accomplishment of result-oriented studies.

Regarding the organization of the content, the structuring of chapter scheme of the book is designed to be more practical in nature. The content of this revised edition is organized into nineteen chapters, well arranged in coherent manner. More details have been added and some new chapters are also incorporated keeping in mind the need of advanced techniques in plant science research. The book provides the basic as well as advanced level discussion on research methodology so that the students and/or the researchers may become familiar with the art of different advanced methods and techniques. This is also a useful source for those writing a thesis or dissertation or a monograph and/or a research paper. The key concepts have been explained so that they can be easily understood by those with little or no research experience. Though the book focuses specifically on issues of research methodology, we have included one chapter that focuses on statistics (biostatistics) wherein we have provided only a simple overview of some of the basic concepts in the field, and for those who intend to conduct detailed analysis, expert consultation is recommended. For some of the chapters where necessary, early history has been added to enable the readers to follow the time line of development.

Writing this book has been an enjoyable journey that we have been encouraged by a number of our students and colleagues teaching botany in and around Anantapur (State of Andhra Pradesh) along the way which served as an impetus for this work. This has been a much bigger project than we originally anticipated, and we hope that we have managed to provide what is required for research in plant science. We have done our best to incorporate all the details as far as possible and the book has run longer than we have expected. We wish to state that every care has been taken to bring out an error-free volume and some errors and omissions, if any, might have been crept in without our knowledge, and if any present, they will be rectified in future editions. Any suggestions for further improvement of the quality of this volume are warmly invited.

Our sincere thanks are due to the authors of Wikipedia, and various other sources of web, books, periodicals, monographs, bulletins, research reports/papers etc. Finally, we express our deep sense of gratitude to the members of our families for their continued cooperation, encouragement and best support in times of stress during the preparation of this volume. Last but not the least, we express our sincere thanks to our Publisher, Scientific Publishers, New Delhi, for their continued cooperation in bringing out this publication in a highly presentable form within a short time.

P. Suresh Narayana
D. Varalakshmi
T. Pullaiah

Anantapur

Dated: 26 January, 2020

CONTENTS

Preface

v

1.	RESEACH METHODOLOGY	1-23
	Introduction	1
	Research - What it is?	1
	Aim and Purpose of Research	2
	Early History of Research	3
	Types of Research	5
	Possible Motives for Doing Research	9
	Methodology - What it is?	10
	Types of Research Methodology	11
	Research Design	13
	Research Plan	14
	Concepts and Context of Research	14
	Research Logistics	14
	Research Methods versus Research Methodology	14
	Research Proposal	15
	Different Stages of Research	15
	Criteria for Good Research	21
	Objectives of Research	22
	Why do people carry out Research?	22
	Importance of Research	22
	Significance of Research	22
2.	CENTRIFUGATION	24-57
	Introduction	24
	Centrifugation - Definition	25
	Types of Centrifugation	25
	Preparative Ultracentrifugation - Separation Methods	26
	Centrifuge - The Instrument	33
	Centrifuge - Components and Parameters	34
	Centrifuge - Operation	34
	Common Centrifuges Used in Biological Sciences	36

Centrifuges - Types	37
Centrifuges - Classification	39
Ultracentrifuge - Basic Principle	42
Preparative Centrifugation - Types of Rotors	42
Rotors - Selection	45
Rotors and Accessories - Care	46
Centrifuge - Containers	47
Density Gradient Separation - Formation and Choice of Density Gradients	48
Gradient Material - Nature and Use	49
Suitable Density Gradient Medium - Selection	49
Fractions - Collection	51
Sample Application to the Gradient	51
Recovery and Monitoring of Gradients	52
Analysis of Sub-cellular Fractions	52
Presentation of the Results	53
Analytical Ultracentrifuge - Applications	53
Centrifuges - Safety Aspects in Use	55
Centrifugation - Applications in Biological Research	55
Many Uses of Centrifuge	56
3. PLANT TISSUE CULTURE	58-86
Introduction	58
Plant Tissue Culture - Materials and Methods	59
Explant	59
Aseptic Environment	59
Tissue Culture Media or Nutrient Media	60
Nutritional Composition of Most Common Plant Cell/Tissue Culture Media (Angiosperms)	61
Composition or Components of Tissue Culture Media	62
General Technique of Plant Tissue Culture	68
Plant Tissue Culture Protocol (General)	73
Plant Tissue Culture - Laboratory and Equipment	74
Methodology for the Establishment of Cultures	77
Types of Plant Tissue Culture	82
Applications of Plant Tissue Culture	83
4. ELECTROPHORESIS	87-118
Introduction	87
Definition	88
How Separation Occurs in Electrophoresis?	88

Requirements for Electrophoresis	88
Basic Principles of Electrophoresis	88
Electrophoresis - Method	89
Factors that affect Electrophoresis	91
Physical Background of Electrophoresis	92
Instrumentation for Electrophoresis	92
Electrophoresis – Apparatus	93
Theory of Electrophoresis	94
Types of Electrophoresis	96
Specific Techniques of Electrophoresis Commonly Used in Biochemistry	100
Detection Methods – Blotting	116
Electrophoresis – Applications	117
RECENT ADVANCES IN ELECTROPHORESIS	118
Introduction	118
Non-linear Frictiophoresis or Non-linear Electrofrictiophoresis	119
ZIFE (Zero Integrated Field Electrophoresis)	119
Pulsed - field Gel Electrophoresis (PFGE)	120
Isotachophoresis (ITP)	121
Transient Isotachophoresis (tITP)	121
Multi-junction IEF System	122
Dielectrophoresis (DEP)	122
Optical Dielectrophoresis	123
Affinity Electrophoresis	123
Difference Gel Electrophoresis (DIGE)	124
Discontinuous Electrophoresis (colloquially Disc Electrophoresis)	124
Microfluidic Chip-based Electrophoresis	125
Iontophoresis	126
Temperature Gradient Gel Electrophoresis (TGGE) and Denaturing Gradient Gel Electrophoresis (DGGE)	127
Free Flow Electrophoresis (FFE) or Carrier-Free Electrophoresis	127
New Technique to Separate Microsatellite Alleles	128
Conclusion	129
5. HERBARIUM TECHNIQUE	130-152
Herbarium - What it is?	130
Plant Collection	131
Why Preserve Plant Specimens?	132
Preservation of the Plant Specimens	132
Equipment Needed for Collection of the Plant Specimens	132

Method of Plant Pressing	138
Method to keep Wet Plant Material in Adverse Conditions	140
Methods of Drying the Plant Specimens	141
What Makes a Good Specimen?	141
The Data to be recorded in the Field Note Books	142
Mounting of the Dry Plant Specimens	147
Labeling the Plant Specimens	148
Filling or Arrangement of the Plant Specimens	149
Special Care of the Plant Specimens	149
Safe Storage of the Sheets / Specimens	150
Safe Preservation of the Specimens (Plants)	151
Use and Significance of the Herbarium	152
Role of Herbarium in Modern Plant Taxonomy	152
6. CHROMATOGRAPHY	153-189
Introduction	153
Definition	154
Principle	154
Chromatography - Early History	155
Classification of Chromatographic Methods	156
Special Techniques of Chromatography	160
Hyphenated (Hybrid) Techniques and Alternative Methods of Detection in Chromatography	161
Chromatography - Basic Principle	161
Types of Chromatography	161
Adsorption Chromatography	162
Partition Chromatography	163
Planar Chromatography	163
General Procedure - Paper Chromatography (PC)	165
Thin Layer Chromatography (TLC)	168
High Pressure Liquid Chromatography (HPLC) or High Performance Liquid Chromatography	171
General Procedure - High-Performance Liquid Chromatography (HPLC)	172
Chromatography - Applications	175
Chromatography - Applications in Biology and Chemistry	177
Chromatography - Uses in Pharmacognosy	177
Chromatography - Applications for the Analysis of Herbal Drugs	178
Chromatography - Latest and Advanced Techniques	179
Evolution of Chromatography	179

Chromatography - Improvements - Multi-dimensional Analysis	180
Dye-Ligand Chromatography	181
Hydrophobic Interaction Chromatography (HIC)	182
Pseudo-affinity Chromatography	183
Immobilized Metal Affinity Chromatography (IMAC)	184
Perfusion Chromatography (PC)	184
Supercritical Fluid Chromatography (SFC)	185
Expanded Bed Adsorption (EBA) Chromatography	185
Nanoflow Liquid Chromatography (NLC)	185
Micellar Liquid Chromatography (MLC)	185
Electrochromatography	186
Capillary Electrochromatography (CEC)	186
Weak Affinity Chromatography (WAC)	187
High Performance Liquid Chromatography (HPLC)	187
Conclusion	188
Hy-phe-nated Techniques or Hybrid Techniques	188
Hy-phe-nated HPLC (High-performance Liquid Chromatography) Methods	188
7. BOTANICAL MICRO-TECHNIQUE	190-208
Introduction	190
Killing and Fixation	191
Embedding the Material in Paraffin	197
Stains and Staining Methods	199
Procedure of Staining	202
Dehydration of the Material	203
Clearing the Sections	204
Dewaxing the Sections	204
Mounting the Material on to the Slide	204
Adhering Sections to the Slides	204
Ringing the Slide / Sealing the Cover slip	205
Slide Label - Preparation	205
Free Hand Sections or Sectioning by Hand	206
Free Hand Sectioning - Procedure	206
Epidermal Peeling - Preparation	207
8. MICROSCOPY	209-233
Introduction	209
Microscopy - Definition	209

Types of Microscopes	209
Optical (Light) Microscope	209
Electron Microscope	211
Scanning Electron Microscope (SEM)	211
Transmission Electron Microscope (TEM)	211
Scanning Probe Microscope (SPM)	211
Optical or Light Microscopy	212
The Compound Light Microscope	214
Electron Microscope	215
Cytophotometry or Microfluorometry	217
Phase Contrast Microscopy (PCM)	218
Fluorescence Microscopy (FM)	220
Scanning Electron Microscopy (SEM)	226
Transmission Electron Microscopy (TEM)	230
Electron Microscopy (EM)	232
9. SMEAR AND SQUASH TECHNIQUE	234-245
Introduction	234
Smear and Squash	235
Squash Technique for Root Tips - Protocol	236
Preparation of the Onion Root Tip Squash	238
Chromosome Squash Technique	243
Preparation of the Anther Smear	244
10. SPECTROPHOTOMETRY	246-260
Introduction	246
History and Spectrophotometry	246
Spectrophotometer - Definition	248
Spectrophotometer - Components	248
Spectrophotometer - Design of the Device	249
Spectrophotometer - Basic Principle	251
Using Spectronic-20 Spectrophotometer	253
Spectrophotometers - Different Types	254
Spectrophotometer - Source of Light	257
Spectrophotometer - Methods of Measurement	258
Spectrophotometer - Uses	259
Spectrophotometer - Applications	259
Colorimeter and Spectrophotometer - Differences	260

11. COLORIMETRY	261-273
Introduction	261
History and Colour/Colorimetry	261
Colorimetry - Definition	262
Colorimeter - The Instrument	263
Principle of Colorimetry	265
Chemistry of Colorimetry	266
Colorimeter - Operational Procedure (Experimental Method)	268
Colorimetry - Chemical Method	269
Absorption Colorimeter	269
Photo-Electric Colorimeter - Operation	269
Colorimetric Assays	270
Precautions to be taken in Colorimetry	270
Factors that affect/influence Colorimetric Measurements	270
Advantages and Disadvantages of a Colorimeter	271
Uses of Colorimeter	271
Colorimetry - Applications in Plant Sciences	272
Colorimetry - Applications in Other Fields	272
12. HYDROGEN-ION CONCENTRATION (pH)	274-302
Introduction	274
Earliest pH Meter - Litmus	274
Hydrogen Ion Concentration (pH)	276
Measurement of pH	279
pH Meter	280
pH Meters - Types	284
Accurate Measurement of pH	284
pH Indicators	285
Buffers and Buffer Solutions	286
Determination of pH	288
Care and Use of pH Meter	290
pH Electrode / pH Meter	290
pH Scale	293
Uses of pH Meters	294
pH Meters - Advantages and Disadvantages	294
pH Controller	294
Calibration of pH Meter - Why?	296
Care of pH Electrodes	296
pH Measurement - Applications	298
pH in Nature	300
pH and Life	301

13.	MICROTOMY AND MICROTOME	303-317
	Introduction	303
	History and Microtomy	303
	Parts of a Microtome	305
	Proposed Classification (Types) of Microtomes	305
	Microtome - Knife Design and Cut Types	312
	Sharpening of the Knives	314
	Method of Sectioning by a Microtome	315
	Maintenance of a Microtome	315
	Applications of a Microtome	316
	Conclusion	317
14.	BIOSTATISTICS	318-356
	Introduction	318
	History and Biostatistics	318
	Scope of Biostatistics	320
	Principles of Experimental Design and Statistical Inference	321
	Tabular Design	324
	Tabular Presentation of the Raw Data	327
	Tabular Presentation of Data	327
	Types of Tables	328
	Best Practice of Presenting the Table	328
	Graphical Design	329
	Diagrammatic Representation of Data	333
	Statistical Method - Types	336
	Data (Information) - Types	336
	Central Tendencies - Measures	337
	Averages	338
	Standard Deviation (SD)	341
	Correlation Coefficient	341
	Standard Error of Mean (SEM) and its Applications	342
	Standard Deviation (SD) and Standard Error (SE)	342
	Confidence Interval (CI) or Fiducial Limits	342
	Distribution - Types	343
	Null Hypothesis μ	344
	Errors - Types	344
	Level of Significance	345
	Outliers	345
	One - tailed and Two - tailed Test	345
	Determination of Sample Size - Importance	346
	Power of Study	347
	Choosing an Appropriate Statistical Test	348

Common Problems Faced by the Researcher	351
Software for Biostatistics	353
Statistical Applications in Biological Research	353
Biostatistics - Applications	355
Recent Development in Modern Biostatistics	355
15. COMPUTERS IN LIFE SCIENCES	357-372
Introduction	357
Computer - Basic Principles	357
Computer - Parts	359
Computers - Types according to Size and Power	362
Brief History of Computing	362
Computers - Applications in Life Sciences	365
Computers in Agricultural Research	367
Computers and Plant Sciences	368
Importance of Computer Literacy and Useful Software for Students and Researchers in Life Sciences	370
16. APPLICATIONS OF RADIOISOTOPES IN BIOLOGY/PLANT SCIENCES	373-387
Introduction	373
Radioactive Isotopes	373
Half-Life ($t_{1/2}$)	374
Half-life in Biology and Pharmacology	374
Radioactive Tracers	374
Tracer Studies / Tracer Techniques	375
Instruments to Measure Ionizing Radiation	376
Geiger-Muller Counter (GM Counter)	376
Scintillation Counter	379
Radioactivity - Applications in Life Sciences	380
Radioisotopes - Applications in Plant Sciences	381
Radioisotopes and Agriculture	381
Radioisotopes - Applications in Agriculture	383
Stable Isotopes - Use in Agriculture	386
Radioisotopes - Uses in Molecular and Cell Biology	387
Conclusion	387
17. BIOINFORMATICS	388-403
Introduction	388
Definition	389
History and Bioinformatics	389
Bioinformatics - Concept and Goal	391

Bioinformatics - Relevance to Biotechnology	392
Bioinformatics - Important Thrust Areas	392
Bioinformatics - Uses	393
Goals of Bioinformatics	394
Approaches of Bioinformatics	394
Bioinformatics in relation to other fields	395
Conclusion	403
18. POLYMERASE CHAIN REACTION (PCR)	404-430
Introduction	404
PCR - What it is?	405
PCR - Principle	405
PCR - General Protocol	406
PCR - Different Schemes and Types	413
Applications of PCR in Different Disciplines	424
PCR - Benefits, Drawbacks and Limitations	429
Conclusion	429
19. PHOTON COUNTING AND PHOTO-MULTIPLIER TUBES (PMTs)	431-452
Introduction	431
Photon Counting	432
Photomultiplier Tube (PMT)	432
Photomultipliers - Properties	436
Photomultipliers - Modification	439
Photon Counting: SPCMs, CPMs and CCDs: Which Technology Works Best?	440
The 3 - Technologies	440
SPCMs (Single Photon Counting Modules)	440
CPMs (Channel Photo Multipliers)	441
CCDs (Charged Coupled Devices)	442
Photon Counting Mode (Analog and Digital)	446
Photon Counting Methods	446
Detectors for High Speed Photon Counting	446
Photon Counting Techniques	446
Detector Principles	450
Photon Detection - Uses	451
Photon Counting - Applications	451
Photon Counting - Benefits	451
Conclusion	452
REFERENCES	453-458