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Clubroot Disease of Crucifers

Biology, Ecology and Disease
Management

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Foreword



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Progress Through Science

Dr. R.S. Paroda
Founder Chairman

FOREWORD

The clubroot is a serious disease of oil yielding *Brassica* crops, including vegetables. It is a potential threat to cruciferous crops covering 2.69 per cent of total cropped area of the world. It is widely distributed all over the world causing both quantitative and qualitative yield losses ranging from 10-100 per cent with world average of 10-15 per cent. In India, it is restricted to a few states. It is widely distributed in Australia, Canada, China, Germany, Japan, Korea, Poland, UK, and USA affecting trade adversely at the international level.

The book entitled "*Clubroot disease of crucifers: Biology, Ecology and Disease Management*" authored by Drs. G. S. Saharan, Former Professor and Head, Department of Plant Pathology, Naresh K. Mehta, Former Assoc. Dean, College of Agriculture, CCS Haryana Agricultural University, Hisar; and Prabhu Dayal Meena, Principal Scientist, DRMR, Bharatpur, is the sixth book on diseases of crucifers being published in series by Springer Nature after the books on *Sclerotinia*, *Albugo*, *Alternaria*, *Hyaloperonospora*, and *Erysiphe*. The book has been written after analysis of world literature with encyclopedic treatment for better comprehension by the readers. The information has been arranged in 15 chapters which have been elucidated with photographs, graphs, tables and figures. Detailed information on major aspects like pathogen, its taxonomy, infection process, pathogenesis, fine structures of the pathogen, biochemistry of host pathogen interaction, pathogenic variability, its distribution, yield losses, disease cycle, epidemiology and forecasting, resistance, its sources, various techniques for germplasm screening, biotechnological approaches, and disease management practices, has been provided in each chapter. The chapter on priority areas of clubroot research will motivate the researchers to undertake further research. On this disease, I am sure this book will serve as a reference document for the Brassicologists for further investigations concerning this important host-parasite system.

I congratulate the authors for bringing out this timely publication. It will be useful for the students, researchers, extension workers and all others concerned with the future growth and development of cruciferous crops.

Dr. R. S. Paroda
Chairman, TAAS &
Former, Secretary (DARE) & DG (ICAR)
Ministry of Agriculture and Farmers Welfare,
Government of India, New Delhi

Preface

The book “*Clubroot Disease of Crucifers: Biology, Ecology, and Disease Management*” is presenting a comprehensive information available in literature on fundamental and applied knowledge of *Plasmodiophora brassicae* Woronin, infecting cruciferous crops and weeds. Clubroot of crucifers which was noticed for the first time in the year 1736 has now spread over more than 88 countries of the world with an average annual loss of crops from 10–15% at a global level. It is considered as a disease of cultivation since once introduced in a field, its inoculum piles up year by year in the form of very hard, resilient to harsh environmental conditions, the resting spores of *P. brassicae* which spreads in the field through cultivation operations. This disease is very unique since the pathogen can survive in the soil in the rhizosphere of non-host plants in addition to its main cruciferous species, cultivated or wild hosts. We have compiled the information generated so far in the form of published reports, research articles, popular scientific articles, books, bulletins, reviews, etc., in this book which are arranged in 16 chapters, with appropriate headings and sub-headings with the sections of references to consult original publications. It is a sixth book on the diseases of cruciferous crops series after *Sclerotinia*, *Albugo*, *Alternaria*, *Hyaloperonospora*, and *Erysiphe* published by Springer Nature. The chapter wise sections include the information, viz., the disease, its geographical distribution, symptoms, host range, yield losses, and disease assessment scales, while detailed description on pathogen includes taxonomic position, phylogeny, variability, sporulation, perpetuation, and resting spore germination; host–parasite interactions in the form of seed infection, disease cycle, process of infection, and pathogenesis, epidemiology, forecasting, fine structures, biochemical changes, host defense mechanism, genetical and molecular mechanisms of host–parasite relationships; genomics of clubroot pathogen and pathogenesis, and management practices including cultural, chemical, biological control practices, and deployment of host resistance and integrated approaches. A chapter on standardized, reproducible techniques has been included for the researchers of cruciferous crops. The last section deals with gaps in our understanding, knowledge about management of the disease, and offers suggestions for future research priorities. The subject matter has been vividly illustrated with photographs, graphs, figures, histogram, tables, and colored plates, which makes it stimulating, effective, and easy to comprehend by the readers. The

headings and sub-headings of each chapter have been arranged in numbered series to make the subject matter contiguous.

We do hope and believe that this book will be immensely useful to the researchers, teachers, extension specialists, students, industrialists, farmers, and all others who are interested to grow healthy and profitable cruciferous crops all over the world. Any suggestions by the readers are always a source of inspiration for the authors. Any shortcomings, lacunae, flaws in the book are responsibility of ours, and suggestions are welcome.

Hisar, India
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Bharatpur, India

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Abbreviations

2-DE	Two-dimensional electrophoresis
ABA	Abscisic acid/abscisic acid
ACC	Aminocyclopropane carboxylic acid
ADK	Adenosine kinase
AFLP	Amplified Fragment Length Polymorphism
ANOVA	Analysis of variance
AUDPC	Area under Disease Progression Curve
AUX	Auxin
B	Boron
BCA	Biocontrol agent
Bj	<i>Brassica juncea</i>
Bn	<i>Brassica napus</i>
Bo	<i>Brassica oleracea</i>
Br	<i>Brassica rapa</i>
bp	Base pairs
BR	Brassinolide
BR	Brassinosteroids
BSGs	<i>Brassica</i> specific genes
Ca (OH) ₂	Calcium hydroxide
CaO	Calcium oxide
CaCO ₂	Calcium carbonate
CaNO ₃	Calcium nitrate
CABI	Centre for Agriculture and Bioscience International
CAPP	Canadian Association of Petroleum Producers
CAZymes	Carbohydrate-active Enzymes
CC	Coiled-coil
CCD	Canadian clubroot differential
CEC	Cation exchange capacity
cDNA	Complementary deoxyribonucleic acid
CHS	Chalcone Synthase
CK	Cytokinins
CMI	Commonwealth Mycological Institute
CR	Clubroot resistant

CSGs	Cruciferae-Specific Genes
CTAB	Cetyltrimethyl Ammonium Bromide
CTOS	Chitin Oligosaccharides
cvs.	Cultivars
CYPs	Cyclophilins
DAB	Diamino-benzidine
DAI/dai	Days after Inoculation/days after inoculation
DAPs	Differentially Accumulated Proteins
DAS	Days after Seeding
DEGs	Differentially Expressed Genes
DH	Doubled Haploid
DI	Disease Index/disease indices/Disease Intensity
DNA	Deoxyribonucleic acid
dpi	Days Post-Infection
DS	Disease Severity
e.g.	For example
EBC	Ethyl Benzimidazol-2-ylcarbamate
ECD	European Clubroot Differential
ECGs	Evolutionary-Conserved Genes
EDTA	Ethylene Diamine Tetraacetic Acid
ELISA	Enzyme-Linked Immunosorbent Assays
EPPO	European and Mediterranean Plant Protection Organization
ESTs	Expressed Sequence Tags
ET/Et	Ethylene
et al.	And others
ETI	Effector Triggered Immunity
f. sp.	Forma specials
FBA	Fructose Bisphosphate Aldolase
FKBPs	FK506-Binding Proteins
FSC	Forest Stewardship Council
FYM	Farmyard manure
g	Gram
GBA	Ground burnt agricultural lime
GBS	Genotyping-by-Sequencing
GC-MS	Gas chromatography–mass spectrometry
GDR	German Democratic Republic
GIS	Geographic Information System
GO	Gene ontology
GPCR	G-protein-coupled receptors
GPS	Global Positioning System
GST	Glutathione s-transferase
<i>GUS</i>	β -glucuronidase
GWAS	Genome-Wide Association Study
h	Hours
ha	Hectare

hpi	Hours Post-Inoculation
HR	Hypersensitive Response
H ₂ SO ₄	Sulfuric acid
IAA	Indole-3-Acetic Acid
IAN	Indole-3-Acetonitrile
IAOx	Indole-3-Acetaldoxime
ICBN	International Code of Botanical Nomenclature
ICP	Inductively Coupled Plasma
ICS	Isochorismate Synthase
ICWG	International Clubroot Working Group
ID	Index of Disease
IG/IGL	Indole glucosinolates
IGS	Intergenic spaces
IP	Intron Polymorphic
IPM	Integrated Pest Management
ISHS	International Society for Horticultural Science
ITS	Internal Transcribed Spacer
JA	Jasmonic Acid
KOH	Potassium hydroxide
kg	Kilogram
LAMP	Loop mediated isothermal DNA amplification
LB	Luria–Bertani
LSGs	Lineage-Specific Genes
LSU	Large subunit
M	Million
MAMPs	Microbe-Associated Molecular Patterns
MAS	Marker-assisted selection
Mb	Million bases
MBC	Benzimidazol-2-ylcarbamate
MeSA	Methyl Salicylate
MgO	Magnesium oxide
min	Minute
miRNA	Micro Ribonucleic acid
MPSS	Massively Parallel Signature Sequencing
MS	Murashige and Skoog
NBS	Nucleotide-Binding Site
NBS-LRR	Nucleotide-Binding Site and Leucine-Rich Repeat
NBSs	Nucleotide-Binding Sites
NCBI	National Center for Biotechnology Information
NGS	Next Generation Sequencing
NILs	Near-Isogenic Lines
NIT	Nitrilase
NPA	N-1-Naphthylphthalamic Acid
NVZs	Nitrate Vulnerable Zones
ORFs	Opening Reading Frames

OSR	Oilseed Rape
P	Phosphorus
PAMP's	Pathogen-associated Molecular Pattern
PAR	Photosynthetically Active Radiation
PCNB	Pentachloronitrobenzene
Pb	<i>Plasmodiophora brassicae</i>
PBP	Bacterial Periplasmic Binding
PCR	Polymerase Chain Reaction
PDA	Potato Dextrose Agar
PFGE	Pulsed-Field Gel Electrophoresis
PMA	Propidium monoazide
ppm	<i>parts per million</i>
PR	Pathogenesis Related
PRRs	Pattern Recognition Receptors
PTI	Pathogen-associated Molecular Patterns-Triggered Immunity
qPCR	Quantitative Polymerase Chain Reaction
QQS	Qua-Quine starch
QTL	Quantitative Trait Loci
R	Resistance
RACE	Rapid Amplification of cDNA Ends
RAPD	Random Amplification of Polymorphic DNA/ Random Amplified Polymorphic DNA
rDNA	Recombinant Deoxyribonucleic acid
RFLP	Restriction Fragment Length Polymorphism
RNA	Ribonucleic acid
rRNA	Recombinant Ribonucleic acid
RISC	RNA Induced Silencing Complex
RLPs	Receptor-like Protein
ROS	Reactive Oxygen Species
RS	Resting Spores
RT-PCR	Real-time PCR
S	Susceptible
SA	Salicylic Acid
SAH	S-adenosylhomocysteine
SAR	Systemic Acquired Resistance
SBP	Solute-Binding Protein
SCAR	Sequence Characterized Amplified Regions
SCF	Skp1-Cullin1-F-Box Protein
SEM	Scanning Electron Microscopy
SNPs	Single-nucleotide Polymorphisms
spp.	Species
SSGs	Small, Spheroids, Resistant-Type Galls/Small Spheroid Galls
SSH	Suppression Subtractive Hybridization
SSI	Single-spore Isolates
SSR	Simple Sequence Repeats