

PERSISTENCE STRATEGIES OF WEEDS



EDITED BY **MAHESH K. UPADHYAYA**
DAVID R. CLEMENTS ■ **ANIL SHRESTHA**

WILEY Blackwell

Table of Contents

[Cover](#)

[Title Page](#)

[Copyright Page](#)

[Biography](#)

[List of Contributors](#)

[Preface](#)

[Foreword](#)

[1 Persistence Strategies of Weeds:](#)

[1.1 Introduction](#)

[1.2 Persistence of Weeds](#)

[1.3 Current Approaches to Manage Weeds and Persistence](#)

[1.4 Conclusions](#)

[References](#)

[2 Seed Production, Dissemination, and Weed Seedbanks](#)

[2.1 Introduction](#)

[2.2 Seed Production](#)

[2.3 Seed Dissemination](#)

[2.4 Weed Seedbank and Seedbank Dynamics](#)

[2.5 Weed Management and Seedbanks](#)

[2.6 Use of Chemicals to Deplete Soil Seedbanks: Potential and Limitations](#)

[2.7 Weed Seed Destruction or Devitalization of Seeds](#)

[2.8 Soil Seedbank Research Methodology](#)

2.9 Conclusions

References

3 Weed Seed Dormancy and Persistence of Weeds

3.1 Introduction: Seed Dormancy and Persistence of Weeds

3.2 Seed Dormancy and Germination

3.3 Types of Seed Dormancy and Some Terminologies

3.4 Dormancy Polymorphism

3.5 Mechanisms of Seed Dormancy

3.6 Coadaptation of Seed Dormancy and Hormonal Regulation of Seed Reserve Mobilization

3.7 Duration of Seed Dormancy and Depletion of Seedbanks During Summer Fallow

3.8 Dormancy Cycling

3.9 Conclusions

References

4 Seed Dormancy Genes and Their Associated Adaptive Traits Underlie Weed Persistence:

4.1 Introduction

4.2 Weedy Rice

4.3 Genetics of Primary Seed Dormancy

4.4 Genes/QTLs Responsible for Associations of Wild-Like Traits with SD

4.5 Genes/QTLs Responsible for Associations of Crop-Mimic Traits with Seed Dormancy

4.6 Conclusions and Implications

Acknowledgements

References

5 Environmental Regulation of Weed Seedbanks and Seedling Emergence

5.1 Introduction

5.2 Germination

5.3 Predation

5.4 Loss of Viability as a Result of Physiological Deterioration

5.5 Dormancy in Seedbanks and Its Control by the Environment

5.6 Germination as Affected by Temperature and Water Availability

5.7 The Functional Ecology of Weed Seedbanks: Concluding Remarks

References

6 Longevity of Weed Seeds in Seedbanks

6.1 Introduction

6.2 Seeds and Seedbanks as Survival Mechanisms

6.3 Role of Seed Longevity in Seedbank Regulation

6.4 Classical Ecological Experiments on Weed Seed Longevity

6.5 Factors Affecting Weed Seed Longevity

6.6 Implications of Seedbank Longevity for Weed Management

6.7 Conclusions and Future Research Directions

References

7 Evolution and Persistence of Herbicide-Resistant Weeds

7.1 Introduction

7.2 How Evolution of Herbicide Resistance Influences Persistence of Weed Populations

[7.3 Case Studies](#)

[7.4 Conclusions](#)

[References](#)

[8 Seed Predation and Weed Seedbanks](#)

[8.1 Introduction](#)

[8.2 Predators and Seed Predation Windows in the Life Cycle of a Weed](#)

[8.3 Seed Defence Versus Seed Selection by Predators](#)

[8.4 Spatiotemporal Variation in Seed Predation](#)

[8.5 The Significance of Seed Predation for the Population Dynamics of Weeds](#)

[8.6 Field and Crop Management Effects on Weed Seed Predation](#)

[8.7 Methodological Aspects of Studying Seed Predation](#)

[8.8 Directions for Future Research and Conclusions](#)

[Acknowledgements](#)

[References](#)

[9 Modelling the Persistence of Weed Populations](#)

[9.1 Why Do We Need Models to Predict Weed Persistence?](#)

[9.2 'Broad-Brush' Ecological Approaches to Modelling Weed Persistence](#)

[9.3 A Process-Based Approach to Modelling Weed Persistence](#)

[9.4 Conclusions](#)

[References](#)

[10 Influence of Agronomic Practices on the Persistence of Weed Seedbanks](#)

[10.1 Introduction](#)

[10.2 Tillage: Vertical Distribution of Seeds Within the Weed Seedbank Influences Weed Seed Persistence](#)

[10.3 Light Penetration and Soil Disturbance Can Reduce Seed Persistence](#)

[10.4 Diverse Crop Rotations Do Not Consistently Reduce Weed Persistence](#)

[10.5 Control of Weed Seed at Harvest Has Potential to Reduce Seed Persistence](#)

[10.6 Role of Cover Crops and Microbial Populations](#)

[10.7 Livestock, Pasture, and Manure Management Can Reduce Weed Seed Persistence](#)

[10.8 Conclusions](#)

[References](#)

[11 Clonal Growth, Resprouting, and Vegetative Propagation of Weeds](#)

[11.1 Introduction](#)

[11.2 Weeding as a Disturbance Regime](#)

[11.3 Plant Strategies Under Recurrent Disturbance](#)

[11.4 Plant Traits Typical for Tolerance Strategies and Resprouting Limitations](#)

[11.5 Tolerance Strategy in an Evolutionary Perspective](#)

[11.6 Conclusions](#)

[Acknowledgments](#)

[References](#)

[12 Climate Change and the Persistence of Weeds](#)

[12.1 Introduction](#)

[12.2 Weed Ecophysiological Responses to Climate Change](#)

[12.3 Predicted Changes in Weed Distribution](#)

[12.4 Impacts of Climate Change on Weed Interactions with Crops](#)

[12.5 Evolutionary Impacts of Climate Change on Weeds](#)

[12.6 Conclusions](#)

[Acknowledgements](#)

[References](#)

[13 Soil Microbial Effects on Weed Seedbank Persistence:](#)

[13.1 Introduction](#)

[13.2 Mechanisms of Microbial Attack](#)

[13.3 Abiotic Environmental Factors](#)

[13.4 Biotic Interactions](#)

[13.5 Seed Defences](#)

[13.6 Weed Management Applications](#)

[13.7 Future Prospects](#)

[Acknowledgements](#)

[References](#)

[14 The Potential Role of Allelopathy in the Persistence of Invasive Weeds](#)

[14.1 Introduction](#)

[14.2 Classification of Allelochemicals](#)

[14.3 Allelochemical Modes of Action](#)

[14.4 Synthesis, Localization, and Release of Allelochemicals from Donor Plants](#)

[14.5 Factors Affecting Biosynthesis and Release of Allelochemicals](#)

[14.6 The Role of Soil Microorganisms in the Release and Transformation of Allelochemicals](#)

[14.7 Metabolic Profiling of Allelochemicals](#)

[14.8 Case Studies of Invasive Plant Species Exhibiting Allelopathic Interactions](#)

[14.9 Conclusions](#)

[References](#)

[15 Weed Adaptation as a Driving Force for Weed Persistence in Agroecosystems](#)

[15.1 Introduction](#)

[15.2 Modes of Weed Evolution](#)

[15.3 The Genetic Basis of Phenotypic Variation in Weedy and Fitness-Related Traits](#)

[15.4 The Contemporary Evolution of Weeds in Agroecosystems: Evidence and Case Studies](#)

[15.5 Applying Evolutionary Thinking to Weed Biology and Management](#)

[15.6 Weed Adaptation: A Key Determinant of Weed Persistence in Agroecosystems](#)

[References](#)

[16 Persistence Strategies of Weeds:](#)

[16.1 Introduction](#)

[16.2 Weed Propagation, Dissemination, and Seed and Vegetative Propagule Banks](#)

[16.3 Weed Seed Dormancy and Longevity](#)

[16.4 Agronomic Practices](#)

[16.5 Predation, Microbial Effects, and Allelopathy](#)

[16.6 Climate Change and Environmental Influences](#)

[16.7 Weed Adaptation and Evolution and Persistence of Herbicide-Resistant Weeds](#)

[16.8 Modeling the Persistence of Weed Populations](#)

[16.9 Conclusions](#)

[References](#)

[Index](#)

[End User License Agreement](#)

List of Tables

Chapter 2

[Table 2.1 Traits associated with survival of plants and how these traits in...](#)

[Table 2.2 Estimates of weed seedbank size in cultivated soils.](#)

Chapter 3

[Table 3.1 A classification system for seed dormancy.](#)

Chapter 4

[Table 4.1 List of seed dormancy_QTLs and their associated adaptive traits i...](#)

Chapter 6

[Table 6.1 The size of the soil weed seedbanks in arable and rangelands sele...](#)

[Table 6.2 Results of Beal's buried seed study.](#)

Chapter 9

[Table 9.1 Which weed species traits related to seedbank persistence are sel...](#)

Chapter 10

[Table 10.1 Estimated seed production for common agricultural weeds found in...](#)

[Table 10.2 Estimated number of seeds in the seedbank under different cropping systems.](#)

[Table 10.3 Impact of crop rotation and tillage system on weed seedbank dynamics.](#)

Chapter 11

[Table 11.1 Bud-bearing organs in weedy species, their description, and examples.](#)

Chapter 12

[Table 12.1 Invasive plant character traits targeted for natural selection.](#)

[Table 12.2 Weed distribution changes related to climate change in North America.](#)

[Table 12.3 Weed distribution changes related to climate change in Europe.](#)

[Table 12.4 Weed distribution changes related to climate change in Oceania.](#)

Chapter 13

[Table 13.1 Base water potentials for weed seed germination and for mycelial growth.](#)

Chapter 14

[Table 14.1 Major classes of allelopathic phytochemicals synthesized by invasive species.](#)

[Table 14.2 Potential mode of action of various allelochemicals associated with invasive species.](#)

List of Illustrations

Chapter 1

[Figure 1.1 Cycle of above- and below-ground natural and human selection and ...](#)

[Figure 1.2 Various species of weeds growing, flowering, and producing seeds ...](#)

Chapter 2

[Figure 2.1 Representative emergence periodicity of summer annual weeds from ...](#)

[Figure 2.2 Components that affect the weed seedbank dynamics.](#)

Chapter 3

[Figure 3.1 Changes in dormancy status of seeds during dormancy cycling in so...](#)

Chapter 4

[Figure 4.1 Seed-related adaptive traits and haplotypes in weedy rice. \(a\) Bl...](#)

Chapter 5

[Figure 5.1 Schematic representation of seedbank dynamics. Inflows are throug...](#)

[Figure 5.2 Schematic representation of changes in seedbank dormancy level af...](#)

[Figure 5.3 Schematic representation of cyclic seasonal changes in seedbank d...](#)

[Figure 5.4 Seasonal changes in the thermal range permissive for seed germina...](#)

[Figure 5.5 Flowchart representing most relevant environmental factors regula...](#)

[Figure 5.6 Schematic representation of the relationship between germination ...](#)

Chapter 6

[Figure 6.1 A model of the soil seedbank budget showing the non-dormant activ...](#)

Chapter 7

[Figure 7.1 The occurrence of double herbicide-resistant \(glyphosate \(RR\) + g...](#)

[Figure 7.2 Pollen-mediated gene flow \(PMGF\) \(% outcrossing\) from glyph...](#)

[Figure 7.3 Multiple herbicide-resistant wild oat in a field in Saskatchewan,...](#)

[Figure 7.4 \(a\) Increase of the percentage frequency of herbicide \(diclofop\)...](#)

Chapter 8

[Figure 8.1 Seed predators. \(a\) Mature larva of *Larinus turbinatus* Gyllenhal ...](#)

[Figure 8.2 Changes in external morphology of *Geum urbanum* L. \(Rosaceae\) seed...](#)

Chapter 9

[Figure 9.1 Schematic of the system that needs to be captured in models of we...](#)

[Figure 9.2 \(a\) Functional group categorization of weeds in terms of seedbank...](#)

[Figure 9.3 Annual seed mortality rate of seeds buried deep in the soil as a ...](#)

[Figure 9.4 X-ray images of seeds of seven weed species with contrasted seed ...](#)

[Figure 9.5 Representation of the parameters used in a model of the change in...](#)

[Figure 9.6 3D individual-based representation of multispecies canopy in FLOR...](#)

[Figure 9.7 Long-term effects of cover \(mustard\) and companion crops \(field b...](#)

Chapter 10

[Figure 10.1 Effect of tillage methods on the vertical distribution of weed s...](#)

Chapter 11

[Figure 11.1 Position of habitats like arable land \(“Anthropogenic”\) in the s...](#)

[Figure 11.2 Examples of vertical distribution of bud banks. In annual plants...](#)

[Figure 11.3 Types of bud-bearing/clonal growth organs in disturbed anthropog...](#)

[Figure 11.4 Spectra of bud-bearing/clonal growth organs in plants along grad...](#)

[Figure 11.5 Possible disturbance regimes for evaluating successful strategie...](#)

Chapter 13

[Figure 13.1 Conceptual model of the various components of the weed soil seed...](#)

[Figure 13.2 Diagram indicating the main niche specialization of *Pyrenophora* ...](#)

[Figure 13.3 Simple conceptual model of the three elements that must be addre...](#)

Chapter 14

[Figure 14.1 Invasive plants are clearly impacted by their environment, and s...](#)

[Figure 14.2 Representative images of invasive plant species presented as cas...](#)

Chapter 15

[Figure 15.1 The 'weed management arms race' is represented here by the coevo...](#)

[Figure 15.2 Selection for seed mimicry in *Vicia sativa* \(common vetch\) cultiv...](#)

[Figure 15.3 Adaptation to hand weeding in *Echinochloa crus-galli* \(barn...](#)

[Figure 15.4 The diversity of documented evolved glyphosate resistance mechan...](#)

Persistence Strategies of Weeds

Edited by

Mahesh K. Upadhyaya

Professor Emeritus, Applied Biology, Faculty of Land and Food Systems, University of British Columbia, Vancouver, BC, Canada

David R. Clements

Professor, Biology and Assistant Dean, Faculty of Natural and Applied Sciences, Trinity Western University, Langley, BC, Canada

Anil Shrestha

Professor, Weed Science and Chair, Dept. of Viticulture and Enology, California State University, Fresno, CA, USA

WILEY Blackwell

This edition first published 2022
© 2022 John Wiley & Sons Ltd

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by law. Advice on how to obtain permission to reuse material from this title is available at <http://www.wiley.com/go/permissions>.

The right of Mahesh K. Upadhyaya, David R. Clements, Anil Shrestha to be identified as the author(s) of the editorial material in this work has been asserted in accordance with law.

Registered Office(s)

John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial Office

The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

For details of our global editorial offices, customer services, and more information about Wiley products visit us at www.wiley.com.

Wiley also publishes its books in a variety of electronic formats and by print-on-demand. Some content that appears in standard print versions of this book may not be available in other formats.

Limit of Liability/Disclaimer of Warranty

The contents of this work are intended to further general scientific research, understanding, and discussion only and are not intended and should not be relied upon as recommending or promoting scientific method, diagnosis, or treatment by physicians for any particular patient. In view of ongoing research, equipment modifications, changes in governmental regulations, and the constant flow of information relating to the use of medicines, equipment, and devices, the reader is urged to review and evaluate the information provided in the package insert or instructions for each medicine, equipment, or device for, among other things, any changes in the instructions or indication of usage and for added warnings and precautions. While the publisher and authors have used their best efforts in preparing this work, they make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives, written sales materials or promotional statements for this work. The fact that an organization, website, or product is referred to in this work as a citation and/or potential source of further information does not mean that the publisher and authors endorse the information or services the organization, website, or product may provide or recommendations it may make. This work is sold with the understanding that the publisher is not engaged in rendering professional services. The advice and strategies contained herein may not be suitable for

your situation. You should consult with a specialist where appropriate. Further, readers should be aware that websites listed in this work may have changed or disappeared between when this work was written and when it is read. Neither the publisher nor authors shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

Library of Congress Cataloging-in-Publication Data applied for

9781119525608

Cover Design: Wiley

Cover Images: Courtesy of Mahesh K. Upadhyaya

Biography

David R. Clements

David R. Clements (PhD, Queen's University) is a Professor of Biology and Assistant Dean of Science at Trinity Western University (TWU) in Canada. He researches invasive weed biology in British Columbia and other parts of the world such as China and Australia and has published extensively. He has served as an Associate Editor for the *Canadian Journal of Plant Science*, *Weed Research*, *Agronomy*, *Pacific Science*, and *Invasive Plant Science and Management* and two series on the biology of invasive species that he helped to create: one in *Pacific Science* and the other in *Invasive Plant Science and Management*. He received the Excellence in Weed Science Award from the Canadian Weed Science Society. He manages TWU's field research sites and teaches courses in botany and ecology, including field courses on Salt Spring Island and Hawaii. He is actively involved in local environmental advocacy and writes *The Green Beat*, a monthly column in the local newspaper.

Mahesh K. Upadhyaya

Mahesh K. Upadhyaya (PhD, University of Michigan) has served as a Professor of Plant Science for nearly four decades and as an Associate Dean of graduate studies in the Faculty of Land and Food System at the University of British Columbia (UBC), where he is currently a Professor Emeritus of Applied Biology. His interests include weed biology and ecology, nonchemical weed management, and crop physiology. He has served as an Associate editor of *Weed Science* journal and the *Canadian Journal of Plant Science* and has co-edited a book (with R.E. Blackshaw), the *Non-chemical Weed Management; Principles, Concepts*

and Technology. He has taught several courses in biology, crop production and protection, different areas of weed science, and postharvest physiology at the UBC. He has received the Killam Teaching Award for outstanding teaching and J.F. Richards Service award at UBC and the Excellence in Weed Science award of the Canadian Weed Science Society. He is a fellow of the Weed Science Society of America, Canadian Weed Science Society, Indian Society of Weed Science, and the Canadian Society of Agronomy.

Anil Shrestha

Anil Shrestha (PhD, Michigan State University) is a Professor of Weed Science and the current chair of the Department of Viticulture and Enology at California State University, Fresno, CA, USA. He works on weed biology, ecology, and management in annual and perennial cropping systems and has published extensively in these areas. He is an Academic Editor for PLOS ONE, an Associate Editor for *Agronomy Journal* and *Agricultural and Environmental Letters*, and an editorial board member for the *Journal of Crop Production* and the *Journal of Agroecology and Sustainable Food Systems*. He is a fellow of the American Society of Agronomy and has received the Weed Science Society of America's teaching excellence award, California Weed Science Society's award of excellence, and the California State University, Fresno Provost's excellence in teaching award.

List of Contributors

Steve W. Adkins

School of Agriculture and Food Sciences
The University of Queensland
Brisbane, QLD
Australia

Michael B. Ashworth

Australian Herbicide Resistance Initiative
School of Agriculture and Environment
The University of Western Australia
Perth, WA
Australia

Ali A. Bajwa

Weed Research Unit
New South Wales Department of Primary Industries
Wagga Wagga, NSW
Australia

Diego Batlla

Facultad de Agronomía
Cátedra de Cultivos Industriales
and Cátedra de Cerealicultura IFEVA (UBA/CONICET)
Buenos Aires
Argentina

Hugh J. Beckie

Australian Herbicide Resistance Initiative
School of Agriculture and Environment
The University of Western Australia
Perth, WA
Australia

Roberto L. Benech-Arnold

Facultad de Agronomía

Cátedra de Cultivos Industriales and Cátedra de
Cerealicultura
IFEVA (UBA/CONICET)
Buenos Aires
Argentina

Fernanda C. Beveridge

School of Agriculture and Food Sciences
The University of Queensland
Brisbane, QLD
Australia

Caio Brunharo

Department of Crop and Soil Science
Oregon State University
Corvallis, OR
USA

Roberto Busi

Australian Herbicide Resistance Initiative
School of Agriculture and Environment
The University of Western Australia
Perth, WA
Australia

Ana L. Caicedo

Biology Department
University of Massachusetts
Amherst, MA
USA

Saul J.P. Carvalho

Department of Agronomy
Federal Institute of Education
Science and Technology of the South Minas Gerais
Machado, Minas Gerais
Brazil

Pedro Christoffoleti

Crop Science Department
Luiz de Queiroz College of Agriculture
University of São Paulo, São Paulo
Brazil

David R. Clements

Department of Biology
Trinity Western University
Langley, BC
Canada

Nathalie Colbach

Agroécologie, AgroSup Dijon
INRAE, Univ. Bourgogne
Univ. Bourgogne Franche-Comté
F-21000, Dijon France

Antonio DiTommaso

Soil and Crop Sciences
School of Integrative Plant Science
Cornell University
Ithaca, NY
USA

Antoine Gardarin

UMR Agronomie
INRAE, AgroParisTech
Thiverval-Grignon
France

Xing-You Gu

Agronomy, Horticulture, and Plant Science Department
Seed Molecular Biology Laboratory
South Dakota State University
Brookings, SD
USA

Saliya Gurusinghe

School of Agricultural
Environmental and Veterinary Sciences
Charles Sturt University
Wagga Wagga, NSW, 2678
Australia

and

Graham Centre for Agricultural Innovation
Charles Sturt University
Wagga Wagga, NSW, 2678
Australia

Linda M. Hall

Department of Agricultural
Food and Nutritional Science
University of Alberta
Edmonton, Alberta
Canada

Alois Honěk

Functional Biodiversity Group
Crop Research Institute
Praha
Czech Republic

Jitka Klimešová

Department of Experimental and Functional Morphology
Institute of Botany of the Czech Academy of Sciences
Třeboň
Czech Republic

and

Department of Botany
Faculty of Sciences
Charles University, Praha
Czech Republic

Sajid Latif

School of Agricultural, Environmental and Veterinary

Sciences
Charles Sturt University
Wagga Wagga, NSW, 2678
Australia

and
Graham Centre for Agricultural Innovation
Charles Sturt University
Wagga Wagga, NSW, 2678
Australia

Li Ma

Institute for Sustainable Horticulture
Kwantlen Polytechnic University
Surrey, BC
Canada

Jana Martínková

Department of Experimental and Functional Morphology
Institute of Botany of the Czech Academy of Sciences
Třeboň
Czech Republic

Helen Metcalfe

Rothamsted Research
Harpenden, Hertfordshire
UK

Alice Milne

Rothamsted Research
Harpenden, Hertfordshire
UK

Nadine Mitschunas

UK Centre for Ecology & Hydrology
Wallingford
UK

Acacio Goncalves Netto

Crop Science Department

Luiz de Queiroz College of Agriculture
University of São Paulo
São Paulo
Brazil

Paul Neve

University of Copenhagen
Department of Plant & Environmental Sciences
Højbakkegård Allé 13
Tåstrup
Denmark

Marcelo Nicolai

Agrocon Agronomic Consulting
Santa Bárbara d'Oeste
São Paulo
Brazil

Pavel Saska

Functional Biodiversity Group
Crop Research Institute
Praha
Czech Republic

Anil Shrestha

Department of Viticulture and Enology
California State University
Fresno, CA
USA

Jonathan Storkey

Rothamsted Research
Harpenden, Hertfordshire
UK

Clarence Swanton

Department of Plant Agriculture
University of Guelph

Guelph, ON
Canada

Mahesh K. Upadhyaya

Faculty of Land and Food Systems
University of British Columbia
Vancouver, BC
Canada

Mark VanGessel

Department of Plant and Soil Science
Research and Education Center
University of Delaware
Georgetown, DE
USA

Saeed Vazan

Department of Plant Agriculture
University of Guelph
Guelph, ON
Canada

Markus Wagner

UK Centre for Ecology & Hydrology
Wallingford
UK

Leslie A. Weston

Graham Center for Agricultural Innovation Charles Sturt
University
Wagga Wagga, NSW, 2678
Australia

Preface

Weeds reduce crop yields, lower the quality of agricultural produce, affect livestock health, and interfere with human life in a variety of ways. A considerable amount of time, money, and other resources are spent in controlling weeds by producers as well as by the general public, yet weeds persist. Unfortunately, we have relied very heavily on the use of synthetic herbicides to control weeds for the past several decades. This has hampered research on other nonchemical options for weed management. It is now well recognized that excessive use of synthetic herbicides carries risks to both the environment and the sustainability of herbicides as a tool. Widespread resistance to herbicides has developed among weed species and for almost all major classes of herbicide chemistry.

Stemming from concerns for human health and the environment, public opposition to the use of synthetic herbicides is progressively increasing. The sustainability of our food production systems is rapidly becoming an important issue globally, and pesticide-free, organic produce is becoming increasingly popular. In order to develop novel and more holistic methods for weed management, a sound understanding of persistence strategies of weeds is necessary. This understanding will help us identify the vulnerabilities of different weeds and could lead to development of novel, safe, and effective weed management strategies by making modifications to our production systems and reduce our dependence on synthetic herbicides. However, because weeds are masters of persistence, have co-evolved with humanity, and are very much the product of how we manipulate agroecosystems and other environments, we need to look beyond short-term

simplistic remedies and understand our complex relationship with weeds.

This book takes a comprehensive approach to understand the persistence of weeds and strives to fill the gap in our understanding of the underlying issues behind the problem of weed persistence and serves as a comprehensive source of information for students, researchers, and weed managers. The various topics covered in this book include an overview of weed persistence, the role of seed production, dissemination and seedbanks, variability in seed dormancy, physiology and genetics of seed dormancy, seed longevity, vegetative propagation and propagule banks, the influence of agronomic practices, allelopathy, predation, soil microbes, climate change, weed evolution, and the development of herbicide resistance. Because weeds and their management are global concerns, specialists from around the world have been selected to write chapters on these topics.

The key learning objective of this book for students and other readers is to enhance understanding of what underpins the persistence strategies of weeds. While this book is aimed to serve upper-level undergraduates and/or graduate students, it can also be used as a reference or text for courses in agroecology and organic agriculture. Weed scientists and weed management professionals working for universities and government agencies, agribusiness consultants, organic farmers, and other environmentally conscious producers will find this book a valuable source of information on persistence strategies of weeds. We also expect this book to stimulate research on development of environmentally friendly weed management options.

We thank all the chapter authors of this book for contributing informative chapters in their areas of

specialization, external reviewers for their critical and constructive reviews of chapter manuscripts, and our families for their cooperation, patience, and encouragement.

Mahesh K. Upadhyaya,
Professor Emeritus, Applied Biology
University of British Columbia
Canada

David R. Clements, and
Professor, Biology
Trinity Western University
Canada

Anil Shrestha
Professor, Weed Science
California State University
USA