EDITED BY

PAUL E. HATCHER AND ROBERT J. FROUD-WILLIAMS

RESEARCH

Expanding Horizons

WILEY

Weed Research

Expanding Horizons

Edited by Paul E. Hatcher and Robert J. Froud-Williams

University of Reading, Reading, UK



This edition first published 2017 © 2017 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 Paul E. Hatcher and Robert J. Froud-Williams to be identified as the authors of editorial material in this work has been asserted in accordance with law.

Registered Office

John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial Office

111 River Street, Hoboken, NJ 07030, USA 9600 Garsington Road, Oxford, OX4 2DQ, UK 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 publisher and the authors 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 fitness for a particular purpose. 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 every situation. In view of ongoing research, equipment modifications, changes in governmental regulations, and the constant flow of information relating to the use of experimental reagents, equipment, and devices, the reader is urged to review and evaluate the information provided in the package insert or instructions for each chemical, piece of equipment, reagent, or device for, among other things, any changes in the instructions or indication of usage and for added warnings and precautions. The fact that an organization or website is referred to in this work as a citation and/or potential source of further information does not mean that the author or the publisher endorses the information the organization or website may provide or recommendations it may make. Further, readers should be aware that websites listed in this work may have changed or disappeared between when this works was written and when it is read. No warranty may be created or extended by any promotional statements for this work. Neither the publisher nor the author shall be liable for any damages arising here from.

Library of Congress Cataloging-in-Publication Data

Names: Hatcher, Paul (Paul E.), editor. | Froud-Williams, R. J., editor.

Title: Weed research: expanding horizons / edited by Paul E. Hatcher and Robert J. Froud-Williams. Description: Hoboken, NJ: John Wiley & Sons Ltd., 2017. | Includes bibliographical references and index. Identifiers: LCCN 2017007880 (print) | LCCN 2017008976 (ebook) | ISBN 9781119969143 (cloth) | ISBN 9781119380603 (pdf) | ISBN 9781119380597 (epub)

Subjects: LCSH: Weeds-Research.

Classification: LCC SB611.3 .W443 2017 (print) | LCC SB611.3 (ebook) | DDC 632/,5072-dc23 LC record available at https://lccn.loc.gov/2017007880

Cover Design: Wiley

Cover Image: Miyako Kondo/EyeEm/Gettyimages

Set in 10/12pt Warnock by SPi Global, Pondicherry, India

Printed in Singapore by C.O.S. Printers Pte Ltd

10 9 8 7 6 5 4 3 2 1

Contents

List of Contributors xvPreface xix

Weed Science Research: Past, Present and Future Perspectives 1 Robert J. Froud-Williams Introduction 1 Factors Influencing the Weed Flora 2 Succession 2 Clean Seed 3 Rotation 3 Fallow 4 Cultivation 5 Straw Burning 5 Soil Amelioration, Drainage and Fertiliser Use 5 Nitrogen 6 Herbicides 6 Consequences of Changing Practices 9 Changing Weed Floras 9 Episodic Decline 13 Weed Spatial Distribution 13 History of Weed Science in the UK and Origins of the Weed Research Organization 14 Origins of the European Weed Research Society 17 Weed Research (Journal): Origin of Papers and Discipline 18 Changing Attitudes to Weeds 18 Set-Aside and Agri-Environment 19 Weeds, Climate and Invasive Aliens 20 Future Directions (Quo Vadis?) 21 Environmental Weed Management 21 Evolutionary Genetics and the Role of Molecular Ecology 22 Is there a Need for a Change of Emphasis? 22 Conclusion 23 Acknowledgements 24 References 24

2	Descriptive and Mechanistic Models of Crop-Weed Competition 33	
	Lammert Bastiaans and Jonathan Storkey	
	Introduction 33	
	Descriptive Models for Yield Loss Due to Weed Competition 34	
	The Hyperbolic Yield Loss-Weed Density Curve 34	
	Accounting for Differences in Relative Time of Emergence 36	
	Other Factors Influencing Parameter i 39	
	Management Aimed at Modifying Crop-Weed	
	Competitive Relations 40	
	A Quantitative Characterisation of Differences in Weed-Suppressive	
	Ability of Crop Cultivars 45	
	Mechanistic Models for Crop-Weed Competition 46	
	Structure and Function of Process-Based Models for Crop-Weed	
	Competition 46	
	A First Application: Ideotyping of More Weed-Suppressive Cultivars 50)
	A Second Application: Predicting the Impact of Climate Change	
	on Weed Distribution 51	
	Conclusion 55	
	References 56	
3	Approaches and Objectives of Arable Weed Species Mapping:	
	Where Next? 61	
	Hansjörg Krähmer and Paolo Bàrberi	
	Weed Species Mapping: Why? 61	
	Scientific Literature: State of the Art 62	
	Mapping Herbicide-Resistant Biotypes 63	
	Mapping Invasive Species 63	
	Weed Species Mapping: Who? 65	
	Weed Species Mapping: Where and What? 66	
	Maps of Weeds in European Arable Crops 66	
	Field-Level Mapping 71	
	Weed Species Mapping: How? 72	
	Geo-Referencing 72	
	Timing of Assessment 74	
	Sampling Parameters 74	
	Documentation and Maps 74	
	What to Conclude from Weed Mapping Data? 75	
	Weed Mapping: Where to Go? 76	
	Acknowledgements 80	
	References 80	
4	Seed Biology and Population Dynamics 85	
	Kirsten S. Tørresen, Laila M. Karlsson and Jose Luis Gonzalez-Andujar	
	Introduction 85	
	Seed Biology 86	
	Seed Production and Dispersal 86	

Seed-Bank 88

Germination and Dormancy 90

Germination 90

Dormancy 91

Sprouting from Vegetative Plant Parts 96

Predicting Seedling Emergence 97

Empirical Models 97

Mechanistic Models 97

Challenges in Predicting Emergence 98

Importance for Weed Control 99

Population Dynamics 100

Dynamics in Time and Space 100

Modelling 100

Non-Spatial Models 101

Spatial Models 103

Practical Applications in Weed Science 103

Evaluation of Management Systems 103

Decision Support Systems 104

Challenges in Modelling Population Dynamics 104

Future Prospects 104

Conclusion 105

Acknowledgements 106

References 106

5 Weeds and Biodiversity 115

Bärbel Gerowitt, Paolo Bàrberi, Henri Darmency, Sandrine Petit, Jonathan Storkey and Paula Westerman

Introduction 115

Arable Weeds in the Context of Biodiversity 116

Functional Biodiversity 116

Agronomic Services and Dis-services Associated with Weeds 117

Genetic Diversity in Weeds 117

How to Measure Genetic Diversity 119

At Which Scale Can Genetic Diversity be Described? 120

Why is it Important to Understand Weed Genetic Diversity? 121

Rare Weed Species as Objects of Conservation 122

Drivers of Arable Weed Declines 123

The Rare Weed Trait Syndrome 124

Conserving Rare Weed Communities 124

Weeds in Food Chains of Arable Systems 124

Factors Influencing Seed-Based Food Webs in Agroecosystems 126

Weed Seed Production 126

Within-Season Temporal Variability 126

Between-Season Temporal Variability 126

Spatial Variability 127

Seed Morphology and Chemistry 127

Weed Diversity 127

Current Status of Seed-Based Food Webs on Farms and Management Options 127

Diversity of Weeds and Arable Management 129 Site Conditions of Arable Fields Shape Weed Communities 129 Methods to Identify and Separate the Influence of Arable Site and Arable Management on Weed Diversity 130 Arable Management Determines Weed Diversity 131 Weed Diversity Versus Weed Abundance 131 Diversity in Weeds Facilitates Management Options 132 Diversity of Weeds in a Landscape Context 133 The Landscape Context of Weeds 133 Conducting Landscape-Scale Weed Studies 134 Landscape Effects on Weed Biodiversity: Empirical Evidence 135 Biodiversity of Weeds in an Economic and Political Context 136 Field Margin Programmes 136 Encouraging Weed Diversity in Farming 136 Conclusions and Perspectives 137 References 138

6 Optimising Herbicide Performance 149

Per Kudsk Introduction 149 Herbicide Classification 150

Optimising Herbicide Performance: How to Study It 151

Biotic Factors 154 Weed Flora 154

Weed Growth Stage 156

Crop Competition 157

Abiotic Factors 158 Soil Texture 158

Climatic Conditions 159

Light 159

Temperature 160

Humidity 161

Precipitation 162

Soil Moisture 163

Wind 164

Concluding Remarks 164

Application Technique 165

Adjuvants 166

Mixtures with Other Herbicides 168

170 Concluding Remarks and Future Challenges

References 172

Herbicide Resistance in Weeds 181

Stephen Moss

Historical Perspective 181

What is Herbicide Resistance? 182

The Worldwide Occurrence of Resistant Weeds 183

Herbicide Mode of Action and Risk of Resistance 185

Resistance Mechanisms 188

Target-Site Resistance 188

PSII (Triazines) 189

ALS Inhibitors 190

ACCase Inhibitors 190

Other Herbicide Classes 191

Non-Target-Site Resistance 191

Reduced Herbicide Uptake 193

Reduced Herbicide Translocation 193

Enhanced Herbicide Metabolism 194

Evolution of Herbicide Resistance 194

Initial Frequency of the Resistance Trait and Size of Weed Population 195

Genetic Basis of Resistance 197

Selection Pressure 199

Frequency of Herbicide Use 199

Persistence of the Herbicide and Pattern of Weed Emergence 199

Intrinsic Activity of the Herbicide and Degree of Resistance Conferred

by the Resistance Mechanism(s) 200

Specificity of the Herbicide: Number of Species the Herbicide Controls 201

Seed-Bank in the Soil 201

Resistance Risk 201

Prevention and Management of Herbicide Resistance 203

Detection of Resistance in the Field 203

Integrated Weed Management 203

Non-Chemical Control Methods 204

Herbicidal Control 204

Alternative Herbicides

Mixtures, Sequences and Rotations 205

Managing Resistance in Alopecurus myosuroides (Black-grass):

A Case Study 205

Farmer Psychology: An Under-Recognised Component

of Resistance Management 206

Conclusion 209

References 209

Weed Biological Control 215

Richard H. Shaw and Paul E. Hatcher

Introduction 215

Definitions of Weed Biocontrol 217

Biocontrol of Weeds in European Extensive Agriculture 218

Cirsium arvense 219

Rumex Species 221

Biocontrol of Weeds in Intensive Agriculture 222

Biocontrol of Non-Native Weeds 224

Ambrosia 228

In Summary 230

Combining Biocontrol with Other Weed Control Techniques 230 Combining with Other Non-Chemical Control Methods 231 Combination with Herbicides 232 Arthropod Biocontrol Agents Fungal Biocontrol Agents 233 Legislation, Responsibilities and Drivers 234 Arthropods 234 Fungi 235 Conclusion 235 References 236

9 Non-Chemical Weed Management 245

Bo Melander, Matt Liebman, Adam S. Davis, Eric R. Gallandt, Paolo Bàrberi, Anna-Camilla Moonen, Jesper Rasmussen, Rommie van der Weide and Francesco Vidotto Introduction 245

Preventive and Cultural Weed Control 246

Objectives, Principles and Practices 247

Objective 1: Reduce Weed Density 247

Objective 2: Reduce Damage Per Surviving Weed 248

Objective 3: Prevent Undesirable Shifts in Weed

Community Composition 249

Current Adoption and Challenges 250

Cover Crops and Mulches 250

Mechanisms of Cover Crop-Weed Interactions 251

Challenges for Research 252

Mechanical Weed Control

How It Works 256

Shortcomings 257

Challenges for Research 258

Thermal Weed Control 259

Thermal Weed Control in Practice 262

Challenges for Research 263

Conclusion 263

References 264

10 Invasive Plants 271

Christian Bohren

Introduction 271

Why Do Invasive Plants Symbolise such a Threat? 271

Invasive Weeds and Human Health 271

Ambrosia 272

Giant Hogweed 273

Weedy Crops, Super Weeds and Mimetic Weeds 274

Invasive Aquatic Weeds 275

Human Intervention 276

Human Curiosity 276

Reasons for Increased Occurrence of Invasive Weeds 276

Responsibility 277

Scientific Prioritisation 278

Popular Prioritisation 278

Implementation 279

Facts Concerning Plant Invasion 280

The Early Beginnings 280

Changing Land Use and Fishery 281

Rapid Adaptation 282

Weeds, Invasives and Climate Change 282

What Makes Plant Invaders so Successful? 283

Can We Predict Plant Invasions? 284

What Has Been Done so Far? 285

Databases 285

European Initiative 285

European Food Safety Agency (EFSA) 288

Euphresco 288

SMARTER 288

Role of the EWRS Invasive Plants Working Group 289

Mission 289

Working Group Activities 289

Ponta Delgada, Azores, Portugal, 2006 289

Osijek, Croatia, 2008 290

Ascona, Switzerland, 2011 290

Montpellier, France, 2014 291

EPPO Trabzon 291

NEOBIOTA 291

Aquatic Weeds 291

Definitions and Plant Lists 292

Definitions 292

Weed 292

Invasive Plant 292

Plant Invader 294

Invasion Trajectory 294

Invasive Species Lists 294

Control Strategies for Invasive Weeds 294

Biological Control Versus Conventional Control 294

Learning to Control Invasions 298

Social and Economic Aspects 300

Anthriscus 300

Japanese Knotweed 300

Bracken 301

Ambrosia 302

Strategies 302

Prevention 302

Early Detection 302

Rapid Response 303

Pest Risk Assessment 303 TO MAKE

Species-Specific Control 303 Conclusion 305 References 306

Parasitic Weeds 313

Maurizio Vurro, Alejandro Pérez-de-Luque and Hanan Eizenberg

Introduction 313

Classification 315

Orobanchaceae (Broomrape Family) 315

Cuscuta 315

Life-Cycle 316

Broomrapes 316

Dodder 317

Distribution at the European Level, Host Range and Yield Losses 318

Management Strategies 325

Management and Control 325

Biological Control 325

Natural Products 328

Strigolactones and Other Germination Stimulants 329

Nanotechnological Approaches 332

Genetic Resistance 334

Defensive Mechanisms 335

Novel Genetic Approaches 337

Chemical Control of Broomrapes 337

Herbicide-Resistant Crops for Broomrape Control 340

Developing Models for Optimising Chemical Control of Root

Parasitic Weeds 341

Precision Agriculture 342

Conclusion 346

References 346

12 Weed Management Systems in Vegetables 355

Francesco Tei and Euro Pannacci

Introduction 355

Weed Flora 357

Weed-Vegetable Crop Interactions 358

Integrated Weed Management 365

Preventive Measures 366

Cultural Methods 366

Crop Rotation 366

Cover-Crops 367

Stale Seed-Bed Preparation 368

Cultivar Selection 368

Planting Method, Planting Pattern, Row Spacing and Crop Density 368

Physical Weed Control 368

Non-Living Mulches 369

Solarisation 369

Flaming 369 Steaming 370 Mechanical Weed Control 370 Hand-Weeding 371 Biological Weed Control 371 Chemical Weed Control 371 Conclusions and Perspectives 377 References 380

13 Perennial Weeds 389

Paul E. Hatcher Introduction 389 Perennating Structures 390 Fragmentation, Nutrient Reserves and Regrowth 391 Dormancy of Vegetative Structures 392 Grassland Perennials 392 Perennials in Organic Arable Systems 394 Perennials of Southern European Agriculture 396 Cyperus Species 397 Sorghum halepense 398 Bracken 399 Conclusion: Perennial Weeds in the Future 401 Climate Change 401 Reduced Tillage 402 References 403

Index 413

WEED RESEARCH Expanding Horizons

This book presents the most up-to-date and comprehensive guide to the current and potential future state of weed science and research. Weeds have a huge effect on the world by reducing crop yield and quality, delaying or interfering with harvesting, interfering with animal feeding (including poisoning), reducing animal health and preventing water flow. They are common across the world and cost billions of dollars' worth of crop losses year on year, as well as billions of dollars in the annual expense of controlling them. An understanding of weeds is vital to their proper management and control, without which the reduction in crop yields that they would cause could lead to mass starvation across the globe.

Topics covered include weed biology and ecology, control of weeds and particular issues faced in their control. Authored and edited by internationally renowned scientists in the field all of whom are actively involved in European Weed Research Society working groups, this succinct overview covers all the relevant aspects of the science of weeds. Weed Research: Expanding Horizons is the perfect resource for botanists, horticultural scientists, agronomists, weed scientists, plant protection specialists and agrochemical company personnel.

PAUL E. HATCHER is Associate Professor in Applied Ecology in the School of Biological Sciences at the University of Reading, working on perennial weed control and biological control of weeds and insects. He has been a member of the EWRS since 1993, and was Chair of the EWRS Biological Control working group for many years. He is Ghair of the Editorial Board for the Wiley-Blackwell journal Weed Research, and a member of the Board of the EWRS. He is also a member of the DEFRA steering group on weed biological control.

ROBERT J. FROUD-WILLIAMS was Senior Lecturer in Weed Science in the School of Biological Sciences at the University of Reading and has research interests in weed ecology, agri-environment and integrated weed management. During his career within the university he supervised more than forty postgraduate students. He has been a member of EWRS since 1980 and was elected Vice President in 2001 and President in 2003 in addition to his former role as National Representative. He has been a member of several external committees including BCPC Expert Weeds and for eighteen years was Chairman of the UK Weed Liaison Group representing publicly-funded weed science in the UK. He also was member of various committees including Defra Sustainable Arable Link, Association of Applied Biology Weeds and Agronomy Group, member of the advisory board for Aquatic Plant Management Committee and steering committee of the Arable Plants Group within Plantlife.

Cover Design: Wiley
Cover Image: © Miyako Kondo/EyeEm/Gettyimages

www.wiley.com





