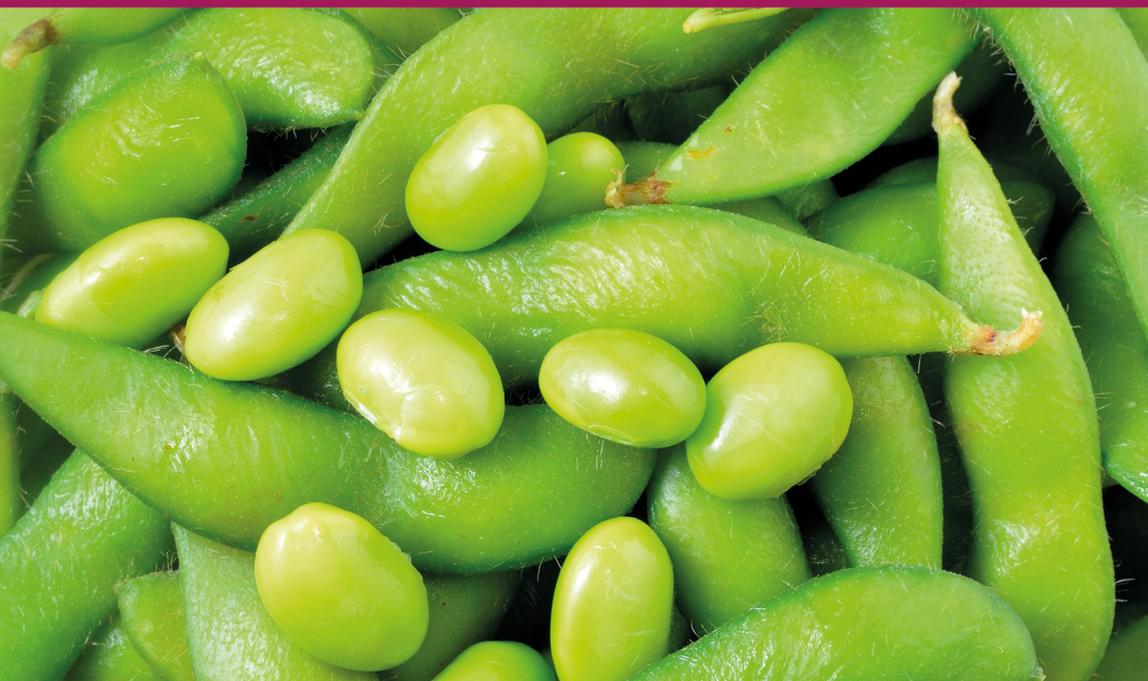


BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE

Achieving sustainable cultivation of soybeans

Volume 2: Diseases, pests, food and other uses

Edited by Professor Henry T. Nguyen
University of Missouri, USA



Contents

Series list	viii
Acknowledgements	xii
Introduction	xiii

Part 1 Diseases, pests and weeds

1	Oomycete and fungal pathogens of soybean	3
	<i>Anne E. Dorrance, The Ohio State University, USA</i>	
	1 Introduction	3
	2 Case studies on diseases caused by Oomycetes	6
	3 Case studies on diseases caused by true fungi: fungal pathogens that affect foliage	10
	4 Case studies on diseases caused by true fungi: fungal pathogens that affect roots	13
	5 Summary	15
	6 Future trends in research	15
	7 Where to look for further information	16
	8 References	16
2	Bacterial and viral diseases affecting soybean production	27
	<i>Glen L. Hartman, USDA-ARS and University of Illinois, USA</i>	
	1 Introduction	27
	2 Bacterial diseases: blight, pustule and tan spot	28
	3 Bacterial diseases: wilts and other bacterial diseases	32
	4 Viral diseases: mosaic and mottle viruses	34
	5 Other viral diseases	37
	6 Summary	39
	7 References	40
3	Nematode pathogens of soybean	47
	<i>T. L. Niblack and H. D. Lopez-Nicora, The Ohio State University, USA</i>	
	1 Introduction	47
	2 General nematode biology	48
	3 Soybean cyst nematodes	50
	4 Root-knot nematodes, <i>Meloidogyne</i> spp.	59
	5 Lesion nematodes, <i>Pratylenchus</i> spp.	63
	6 Reniform nematodes	65
	7 Lance nematodes, <i>Hoplolaimus</i> spp.	68
	8 Other nematodes	69
	9 Conclusion	70
	10 Where to look for further information	71
	11 References	72

4	Key factors limiting sustainable insect pest management in soybeans <i>M. E. O'Neal, Iowa State University, USA; and R. Cox, EarthEmpower Consulting and Investment, Mexico</i>	87
1	Introduction	87
2	Invasive species	90
3	Insect resistance management (IRM), especially for Bt-soybeans	95
4	Conclusion	97
5	Future trends	98
6	Where to look for further information	99
7	References	99
5	Advances in disease-resistant varieties of soybean <i>David R. Walker, USDA-ARS, USA</i>	105
1	Introduction	105
2	Resistance to major soybean diseases and nematode pests	108
3	Selection for disease resistance	126
4	Contribution of soybean genomics research to breeding strategies	127
5	Pathogen genomics	128
6	Disease resistance from <i>G. soja</i> and perennial <i>Glycine</i> species	128
7	Transgene-mediated disease resistance	129
8	Summary and future trends	129
9	Where to look for further information	131
10	References	131
6	Advances in pest-resistant varieties of soybean <i>Shichen Zhang and Dechun Wang, Michigan State University, USA</i>	145
1	Introduction	145
2	Mechanisms of HPR	147
3	Insect resistance in the soybean germplasm	148
4	Breeding challenges	154
5	<i>Bacillus thuringiensis</i> (Bt) soybean	155
6	Case study: developing aphid-resistant varieties	156
7	Conclusion	161
8	Future trends	166
9	Where to look for further information	166
10	References	166
7	Integrated weed management in soybean cultivation <i>Bob Hartzler, Iowa State University, USA</i>	175
1	Introduction	175
2	Establishing weed-management goals	176
3	Management tactics: crop rotation, competitiveness of soybean and use of cover crops	178
4	Further management tactics	181
5	Interactions between weeds and other pest complexes	184
6	Factors limiting the adoption of diversified weed management	185
7	Conclusion	185
8	Where to look for further information	186
9	References	186

Part 2 Food and other uses

8	Nutritional, nutraceutical and functional properties of soybeans	195
	<i>Suzanne Hendrich, Iowa State University, USA</i>	
1	Introduction	195
2	Nutritional effects of soybean oils	196
3	Nutritional and nutraceutical functions of soybean proteins in cardiovascular disease	197
4	Health effects of soybean proteins and associated constituents	198
5	Other health or adverse effects of soybean foods and ingredients	202
6	Conclusion and future trends	204
7	References	204
9	Improving the nutritional value of soybean	209
	<i>Istvan Rajcan and Jocelyne Letarte, University of Guelph, Canada</i>	
1	Introduction	209
2	Soybean protein content and profile	210
3	Soybean oil profile	214
4	Tocopherols	217
5	Isoflavones	220
6	Saponins	222
7	Future trends and conclusion	223
8	References	224
10	Allergens in soybean	235
	<i>Eliot M. Herman, University of Arizona, USA</i>	
1	Introduction	235
2	Clinical allergies to soybean	236
3	Infant food allergies and intolerance	237
4	Soybean IgE-binding proteins	238
5	Mitigating soybean allergens	241
6	Soybean intolerance in aquaculture	245
7	Food allergy, biotechnology and the risk of extrinsic introduced allergens	246
8	Summary	248
9	Where to look for further information	248
10	Acknowledgements and dedication	248
11	References	248
11	Nutritional considerations for soybean meal use in poultry diets	257
	<i>Justin Fowler, University of Georgia, USA</i>	
1	Introduction	257
2	Nutritional content of SBM	258
3	Anti-nutritive compounds	260
4	Genetically modified soybeans	263
5	Conclusion and future trends	264
6	Where to look for further information	265
7	References	265
	Index	267

Introduction

Soybeans are one of the most widely-grown crops in the world. As the world's main source of vegetable protein, they have a wide range of food and non-food uses. Current yields need to increase significantly to meet growing demand but in a way that reduces input use, does not damage the environment and is resilient to climate change. These challenges are addressed in the two volumes of *Achieving sustainable cultivation of soybeans*:

- Volume 1: Breeding and cultivation techniques
- Volume 2: Diseases, pests, food and other uses

Volume 2 reviews advances in understanding and managing the range of diseases and pests that continue to cause significant crop losses. The volume offers detailed coverage of oomycete, fungal, viral and bacterial diseases affecting soybeans. It reviews developments in disease and pest-resistant varieties of soybean as well as integrated pest and weed management. Finally, the volume summarises research on developing the food and non-food uses of soybean, from improving nutritional properties to uses in animal feed and biodiesel.

Part 1 Diseases, pests and weeds

Soybean losses due to diseases of all kinds are estimated to be about 14% of total soybean production. Part 1 discusses fungal, viral and bacterial diseases as well as developments in disease-resistant varieties and integrated pest and weed management. Chapter 1 provides an overview of oomycete and fungal pathogens of soybean. Soybean production faces numerous biotic challenges, leading to significant yield losses each year. The chapter presents case studies on the oomycete pathogens *Phytophthora sojae* and the *Pythium* species and the true fungi *Cercospora sojae*, *Phakopsora pachyrhizi*, *Macrophomina phaseolina* and the *Fusarium* species. Through these case studies, the chapter emphasizes the diversity of the pathogens which affect soybean, including their genetic diversity, different modes of infection and different host ranges, focusing especially on pathogens that affect roots and foliage. The chapter also considers the diverse range of management options, as well as future trends in research which should improve our ability to manage soybean diseases.

Chapter 2 moves from oomycete and fungal pathogens to consider bacterial and viral diseases affecting soybean production. The chapter reviews bacterial blight, pustule, tan spot and wilt, as well as a few other bacterial diseases affecting soybean. It then discusses in detail some important viral diseases of soybean, namely alfalfa mosaic virus, bean pod mottle virus, soybean mosaic virus, soybean vein necrosis virus, tobacco ringspot virus, and tobacco streak virus. The chapter also considers how the impact of bacterial and viral pathogens can be mitigated through management practices such as crop rotation, utilization of pathogen-free seed, better use of synthetic and non-synthetic pesticides for vector control, and deployment of resistant cultivars. Chapter 3 considers another important group of soybean pests: nematodes. The chapter examines the origins and management of a variety of parasitic nematodes affecting soybean,

including soybean cyst nematodes, root-knot nematodes, lesion nematodes, reniform nematodes and lance nematodes. The chapter also reviews nematode resistance in soybean.

Complementing the focus of the first three chapters on specific soybean pests, Chapter 4 concentrates on integrated pest management (IPM) for soybean. The chapter includes a detailed case study on the development of an IPM program for an invasive soybean pest (the case of soybean aphid in the US Midwest). The chapter also examines programmes to manage multiple pests in South America and assesses the barriers to achieving sustainable pest management.

Chapter 5 then reviews recent advances in disease-resistant varieties of soybean. Advances in breeding techniques have facilitated the development of soybean cultivars with broader and more durable resistance, but continued reliance on a small number of major resistance genes remains a concern. Introgression of resistance genes from unadapted germplasm sources with a reduced risk of linkage drag has become more efficient with marker-assisted selection. Advances in DNA sequencing and other technologies have made it possible to identify novel resistance loci and candidate genes. The chapter summarizes what is currently known about resistance to some of the major diseases affecting soybean production, particularly in North America, and genes that condition resistance to those diseases. It explores the possibilities of selection for disease resistance, as well as assessing the contribution of soybeans genomics research to breeding strategies. The chapter also examines the genomics of the pathogens themselves, and focuses particularly on disease resistance from *Glycine soja* and perennial *Glycine* species, as well as discussing transgene-mediated disease resistance.

Complementing Chapter 5, Chapter 6 moves on to discuss advances in pest-resistant varieties of soybean. A number of insect pests have been threatening soybean production in North America, including lepidopteran defoliators, coleopteran defoliators and hemipteran sap-suckers. Among various control methods, host-plant resistance has been of the greatest interest as it is economically and environmentally friendly. The chapter reviews recent advances in research on improving soybean with host-plant resistance in North America, and discuss challenges of developing highly insect-resistant cultivars with competitive yield performance. The chapter discusses attempts to genetically engineer soybean with Bt insecticidal protein genes as well as gene pyramiding in order to gain broad and durable resistances against multiple insects. The chapter also includes a case study on key issues in developing aphid-resistant varieties.

Concluding the first part of the volume, Chapter 7 examines the challenge of integrated weed management in soybean cultivation. Almost all soybean fields have a weed infestation that must be managed for farmers to sustain economic viability. The chapter reviews the practicalities of integrated weed management, which combines plant breeding, cultural, mechanical and chemical practices in suppressing weed populations and minimizing the impacts of weeds on yield. After establishing the importance of a diverse weed management strategy, the chapter examines how farmers set goals for weed management and the importance of focusing on managing the weed seed bank. The chapter then reviews the wide range of management tactics available, and considers interactions between weeds and other pests. Finally, the chapter discusses the factors which limit the adoption of integrated weed management.

Part 2 Food and other uses

The second part of the volume addresses food uses of soybean and other non-food uses. Chapter 8 is devoted to the nutritional, nutraceutical and functional properties of soybeans. Soybeans have desirable nutritional properties, since they contain about twice the protein of other legumes per serving. The chapter examines recent research on the nutritional and nutraceutical efficacy of soybean foods and food or dietary supplement ingredients, including soybean oils, proteins, isoflavones and other compounds for which soybeans are a significant source.

Building on the theme of Chapter 8, Chapter 9 focusses on improving the nutritional value of soybean. Soybean is grown for its high oil and protein concentration in the seed. Numerous studies have been carried out to determine the underlying genetics of soybean seed composition traits and develop molecular markers that can aid in the breeding of soybean cultivars with enhanced nutritional quality. The chapter considers genetics and breeding of soybean to improve the nutritional value of the seed as the end product. The chapter describes the protein content and profile of soybean seeds before considering breeding soybean for a modified fatty acids profile that could extend the shelf life of soybean oil or enhance nutritional and nutraceutical function. Finally, the chapter explores how breeding could improve the content of tocopherols, isoflavones and saponins in soybean seeds, which are known to have important health benefits for humans.

Continuing the focus on the use of soybean as a food source, Chapter 10 considers the problem of allergens in soybean. Soybean protein is one of the most significant sources of food allergens and intolerance, causing both IgE-mediated allergy and food protein induced endocolitis syndrome (FPIES). The chapter first discusses the mechanisms causing allergies and infantile food intolerance. It reviews what we know about adverse food responses, the gut's response to food, the multiple IgE binding proteins in soybean as well as P34, the major soybean allergen. The chapter also discusses how to reduce allergens in soybean plants as well as the particular problem of intolerance in salmonids with implications for aquaculture. The chapter also examines the challenge of mitigating soybean allergens, assessing the potential role of biotechnology and the risk of extrinsically-introduced allergens.

The volume's final chapter, Chapter 11, moves to considering soybean as a source of animal feed, addressing the nutritional considerations for soybean meal use in poultry diets. The poultry feed industry uses about 50% of the soybean meal (SBM) produced in the USA each year. The meal is valuable to the animal feed industry because it is an excellent source of amino acids that would otherwise be lost to the human food chain after the oil has been removed from the bean. The chapter assesses the nutritional content of SBM, as well as its anti-nutritive compounds, and considers the effects of genetic modification on improving SBM as a poultry feed.

Index

- Alfalfa mosaic virus* 34–35
- Allergens, in soybean
and biotechnology 246–247
clinical allergies 236–237
infantile food intolerance 237
IgE-binding proteins 238–241
infant food allergies and
intolerance 237–238
intolerance in aquaculture 245–246
mitigating 241–245
overview 235–236
- Anthraxnose 113
- Aphid-resistant varieties 156–161
- Bacillus thuringiensis* (Bt) 155
- Bacterial diseases
bacterial blight 28–29, 109
bacterial pustule (BP) 29–31, 109–110
bacterial tan spot 31–32
bacterial wilts 32
other 32–33
overview 27–28
- Bacterial pustule (BP) 29–31, 109–110
- Bacterial tan spot 31–32
- Bacterial wilts 32
- Bean pod mottle virus* 35–36
- Biochemical resistance, and HPR 148
- Biological control 182–183
- Biotechnology, and soybean allergens 246–247
- BP. see Bacterial pustule (BP)
- Browning reaction 261
- Brown stem rot (BSR) 113–114
- BSR. see Brown stem rot (BSR)
- Cercospora sojina* 10–11
- Charcoal rot 114
- Coleopteran pests 148–149
- Cover crops 180–181
- Crop rotation 178–179
- Disease-resistant varieties
by bacteria
bacterial blight 109
bacterial pustule (BP) 109–110
by fungal pathogens
anthracnose 113
brown stem rot (BSR) 113–114
charcoal rot 114
frogeye leaf spot (FLS) 114–115
Phomopsis seed decay 115–116
Rhizoctonia damping-off and root
rot 116–117
Sclerotinia stem rot 117–119
soybean rust 119–121
stem canker 121
sudden death syndrome 122
G. soja and perennial *Glycine*
species 128–129
genomics research 127–128
nematodes
root-knot nematodes 125–126
soybean cyst nematode 123–125
by oomycetes 110
overview 105–108
pathogen genomics 128
Phytophthora root and stem rot 110–112
Pythium rot and damping-off 112
selection for 126–127
transgene-mediated 129
- FLS. see Frogeye leaf spot (FLS)
- Frogeye leaf spot (FLS) 114–115
- Fungal pathogens
anthracnose 113
brown stem rot (BSR) 113–114
Cercospora sojina 10–11
charcoal rot 114
frogeye leaf spot (FLS) 114–115
Fusarium species 14–15
Macrophomina phaseolina 13
overview 3–6
Phakopsora pachyrhizi 12–13
Phomopsis seed decay 115–116
Rhizoctonia damping-off and root
rot 116–117
Sclerotinia stem rot 117–119
soybean rust 119–121
stem canker 121
sudden death syndrome 122
Fusarium species 14–15
- G. soja* and perennial *Glycine* species 128–129
- Genetically modified organism (GMO) 263–264
- GMO. see Genetically modified organism (GMO)
- Hemipteran pests 152–153
- Herbicides 183
- Heterodera glycines* biology 51–52
- Host-plant resistance (HPR)
Bacillus thuringiensis (Bt) 155
biochemical resistance 148
breeding challenges 154–155
and coleopteran pests 148–149
developing aphid-resistant
varieties 156–161
and hemipteran pests 152–153
and lepidopteran pests 149–152
overview 145–147
pubescence-related resistance 147–148
HPR. see Host-plant resistance (HPR)

- IgE-binding proteins 238–241
- Infant food allergies and intolerance 237–238
- Infantile food intolerance 237
- Insect resistance management (IRM) 95–97
- Integrated pest management 88–89
- Integrated weed management
- biological control 182–183
 - cover crops 180–181
 - crop rotation 178–179
 - enhancing competitiveness 179–180
 - establishing goals 176–177
 - factors limiting 185
 - herbicides 183
 - impacts of 176
 - managing weed seed bank 177–178
 - mechanical control 181–182
 - overview 175–176
 - pest complexes 184
 - scouting/mapping 183–184
 - soil management 182
- Invasive species 90–94
- IRM. *see* Insect resistance management (IRM)
- Isoflavones 220–222, 263
- Lance nematodes 68–69
- Lepidopteran pests 149–152
- Lesion nematodes
- diagnosis 63–64
 - management 65
- Macrophomina phaseolina* 13
- Mechanical control 181–182
- Nematodes
- general biology 48–50
 - lance nematodes 68–69
 - lesion nematodes
 - diagnosis 63–64
 - management 65
 - overview 47–48
 - reniform nematodes
 - life cycle and disease cycle 65–67
 - management 67–68
 - root-knot nematodes 125–126
 - description 59–60
 - diagnosis 62
 - life cycle and disease cycle 61
 - management 62–63
 - soybean cyst nematode 123–125
 - biotic disease interactions 53–54
 - genetic diversity 54–56
 - Heterodera glycines* biology 51–52
 - management 57–59
 - origin and distribution 50
 - population dynamics 53
 - resistance to *Heterodera glycines* 56–57
- Non-starch polysaccharides 262–263
- Nutraceutical functions
- in cardiovascular disease 197–198
 - effects of soybean oils 196
 - effects on blood glucose and diabetes 198–199
 - effects on blood pressure, kidney and arterial function 198
 - effects on cancer risk 199–200
 - effects on cognition 202
 - effects on menopause 200–201
 - effects on obesity 199
 - other health or adverse effects 202–204
 - overview 195–196
- Nutritional values
- browning reaction 261
 - description 258–259
 - genetically modified organism (GMO) 263–264
 - isoflavones 220–222, 263
 - non-starch polysaccharides 262–263
 - and nutraceutical functions
 - in cardiovascular disease 197–198
 - effects of soybean oils 196
 - effects on blood glucose and diabetes 198–199
 - effects on blood pressure, kidney and arterial function 198
 - effects on cancer risk 199–200
 - effects on cognition 202
 - effects on menopause 200–201
 - effects on obesity 199
 - other health or adverse effects 202–204
 - overview 195–196
 - oil profile 214–217
 - overview 209–210, 257–258
 - protein content and profile 210–213
 - saponins 222–223
 - tocopherols 217–220
 - trypsin inhibitors 260–261
- Oomycetes
- disease-resistant by 110
 - Phytophthora sojae* 6–9
 - Pythium* spp. 9–10
- Pathogen genomics 128
- Phakopsora pachyrhizi* 12–13
- Phomopsis* seed decay 115–116
- Phytophthora* root and stem rot 110–112
- Pubescence-related resistance 147–148
- Pythium* rot and damping-off 112
- Reniform nematodes
- life cycle and disease cycle 65–67
 - management 67–68
- Rhizoctonia* damping-off and root rot 116–117
- Root-knot nematodes 125–126
- description 59–60
 - diagnosis 62

- life cycle and disease cycle 61
 - management 62–63
- Saponins 222–223
- SBM. *see* Soybean meal (SBM)
- Sclerotinia* stem rot 117–119
- Scouting/mapping 183–184
- Soil management 182
- Soybean allergens
 - and biotechnology 246–247
 - clinical allergies 236–237
 - infantile food intolerance 237
 - IgE-binding proteins 238–241
 - infant food allergies and
 - intolerance 237–238
 - intolerance in aquaculture 245–246
 - mitigating 241–245
 - overview 235–236
- Soybean cyst nematode 123–125
 - biotic disease interactions 53–54
 - genetic diversity 54–56
 - Heterodera glycines* biology 51–52
 - management 57–59
 - origin and distribution 50
 - population dynamics 53
 - resistance to *Heterodera glycines* 56–57
- Soybean meal (SBM) nutritional
 - considerations for
 - browning reaction 261
 - description 258–259
 - genetically modified organism (GMO) 263–264
 - isoflavones 219–222, 263
 - non-starch polysaccharides 262–263
 - oil profile 214–217
 - overview 209–210, 257–258
 - protein content and profile 210–213
 - saponins 222–223
 - tocopherols 217–220
 - trypsin inhibitors 260–261
- Soybean mosaic virus* 36–37
- Soybean rust 119–121
- Soybean vein necrosis virus (SVNV) 37–38
- Stem canker 121
- Sudden death syndrome 122
- Sustainable insect pest management
 - insect resistance management (IRM) 95–97
 - and integrated pest management 88–89
 - invasive species 90–94
 - overview 87–88
 - in the United States 89–90
- SVNV. *see* Soybean vein necrosis virus (SVNV)
- Tobacco ringspot virus* 38–39
- Tobacco streak virus* 39
- Tocopherols 217–220
- Transgene-mediated disease-resistant 129
- Trypsin inhibitors 260–261
- Viral diseases
 - Alfalfa mosaic virus* 34–35
 - Bean pod mottle virus* 35–36
 - overview 34
 - Soybean mosaic virus* 36–37
 - soybean vein necrosis virus (SVNV) 37–38
 - Tobacco ringspot virus* 38–39
 - Tobacco streak virus* 39