

Contents

<i>Preface to the Series</i>	vii
<i>Preface to the Volume</i>	xiii
<i>List of Contributors</i>	xxiii
<i>List of Abbreviations</i>	xxv
1. Basic Information	1
<i>Gerald Seiler and C.C. Jan</i>	
1.1 Introduction	2
1.2 Economic Importance	2
1.2.1 World Production Area	2
1.2.2 Nutritional Information	3
1.2.2.1 Oil and Oil Quality	3
1.2.2.2 Protein	5
1.2.2.3 Tocopherol Composition	6
1.3 Crop History	7
1.3.1 Origin and Domestication	7
1.3.2 Dispersion	9
1.4 Botanical Description	11
1.4.1 Taxonomic Position	11
1.4.2 Plant Structure and Growth Habit	16
1.4.3 Habitat	19
1.4.4 Karyotype	19
1.4.5 Polyploidy	20
1.4.6 Aneuploidy	21
1.4.7 Genome size	22
1.5 Genetic Resources	22
1.5.1 Primary Gene Pool	22
1.5.2 Secondary and Tertiary Gene Pools	25
1.5.3 Ex situ <i>Helianthus</i> Collection	25
1.5.4 Core Collection	27
1.5.5 Wild Species Utilization	28
1.5.5.1 Pathogen Resistance	28
1.5.5.2 Viral and Bacterial Resistance	29
1.5.5.3 Insects	29

1.5.5.4 Oil and Oil Quality	29
1.5.5.5 Cytoplasmic Male Sterility	30
1.5.5.6 Salt Tolerance	31
1.5.5.7 Herbicide Tolerance	31
1.5.6 Cytogenetic Stocks	31
1.5.7 Mutagenesis	33
1.5.8 Genetic Stocks	34
1.6 Importance as a Model Plant	35
1.6.1 Speciation	35
1.6.2 Interspecific Hybridization	35
1.6.3 Gene Flow	36
1.6.4. Genetic Diversity	38
1.7 Conclusions	39
References	40
2. Classic Genetics and Breeding	51
<i>Felicity Vear</i>	
2.1 Introduction	51
2.2 Hybrids	52
2.3 Breeding Methods	54
2.3.1 Mass Selection	54
2.3.2 Recurrent Selection	54
2.3.3 Pedigree Selection	55
2.4 Breeding Objectives	56
2.4.1 Seed Yield	56
2.4.2 Oil Content and Oil Quality	59
2.4.3 Cycle Length	61
2.4.4 Disease Resistance	61
2.4.4.1 Disease Controlled Mainly by Major Gene Resistance	62
2.4.4.1.1 Downy Mildew (<i>Plasmopara halstedii</i>)	62
2.4.4.1.2 Broomrape (<i>Orobanche cumana</i>)	65
2.4.4.2 Quantitative Resistance	66
2.4.4.2.1 White rot (<i>Sclerotinia sclerotiorum</i>)	66
2.4.4.2.2 Phomopsis (<i>Diaporthe helianthi</i>)	68
2.4.5 Insects Affecting Seed Yield	69
2.4.6 Drought Resistance	69
2.4.7 Resistance to High and Low Temperatures	70
2.4.8 Lodging Resistance and Reduced Height	70
2.5 Classic Genetic Mapping and Cytogenetics	71
2.6 Interest of Molecular Maps and Knowledge of Genomics for Conventional Genetics and Breeding	71
2.7 The Introduction of Genomics in Breeding Since 1995	73
References	73

3. Genetic Linkage Maps: Strategies, Resources and Achievements	79
<i>Jinguo Hu</i>	
3.1 Introduction	80
3.2 Brief History of Mapping Efforts: Morphological and Biochemical Markers	80
3.2.1 Morphological Markers	80
3.2.2 Biochemical Markers	81
3.2.2.1 Isozyme Markers	81
3.2.2.2 Storage Protein Markers	84
3.3 DNA-based Marker Techniques	84
3.3.1 RFLP	85
3.3.2 RAPD	85
3.3.3 AFLP	86
3.3.4 DALP	87
3.3.5 SSR	88
3.3.6 TRAP	89
3.3.7 SNP	90
3.3.8 Markers from DNA Sequence Databases	91
3.4 Mapping Populations and Tools	91
3.4.1 Mapping Populations	91
3.4.2 Mapping Software Packages	92
3.4.2.1 MapMaker	93
3.4.2.2 JoinMap	93
3.4.2.3 GMendel	94
3.5 Achievement	94
3.5.1 RFLP Maps	94
3.5.2 AFLP Maps	95
3.5.3 SSR Maps	96
3.5.4 TRAP Maps	97
3.6 Published Sunflower Linkage Maps	97
3.7 Challenges	98
References	103
4. Mapping and Tagging of Simply Inherited Traits	111
<i>Volker Halm and Silke Wieckhorst</i>	
4.1 Introduction	111
4.2 Disease Resistances	116
4.2.1 Resistance to Downy Mildew	116
4.2.2 Rust Resistance	121
4.2.3 Resistance to Sunflower Chlorotic Mottle Virus	121
4.2.4 Broomrape Resistance	121
4.3 Herbicide Resistance	123

4.4 Male Sterility	124
4.4.1 Restoration of Cytoplasmic Male Sterility	124
4.4.2 Nuclear Male Sterility	124
4.5 Morphological Traits	125
4.5.1 Branching	125
4.5.2 Leaf and Ray Color	125
4.6 Seed Quality	126
4.6.1 Oil Quality	126
4.6.2 Tocopherol Composition	127
References	128
5. Molecular Mapping of Complex Traits	135
<i>Seifollah Poormohammad Kiani and Ahmad Sarrafi</i>	
5.1 Introduction	135
5.2 Identification of Quantitative Trait Loci	136
5.2.1 Agronomic Traits	136
5.2.1.1 Days from Sowing to Flowering	136
5.2.1.2 Agro-morphological Traits	145
5.2.1.3 Oil Content and Yield-related Traits	147
5.2.2 Disease Resistance	151
5.2.2.1 Resistance to <i>Downy Mildew</i>	151
5.2.2.2 Resistance to <i>Diaporthe helianthi</i>	151
5.2.2.3 Resistance to <i>Phoma macdonaldii</i>	152
5.2.2.4 Resistance to <i>Sclerotinia sclerotiorum</i>	153
5.2.2.5 Resistance to <i>Orobanche cumana</i>	157
5.2.3 Self-incompatibility and Seed Dormancy	158
5.2.4 Fertility Restoration and Male Sterility	158
5.2.5 Physiological Traits	159
5.2.6 In vitro Regeneration	159
5.2.7 Abiotic Stress Tolerance	160
5.2.7.1 Plant Water Status and Osmotic Adjustment	160
5.2.7.2 Yield and Related Traits under Drought Conditions	161
5.3 Conclusion	166
References	166
6. Gene Cloning and Characterization	173
<i>Renate Horn and Sonia Hamrit</i>	
6.1 Introduction	174
6.2 Map-based Cloning Approaches in Sunflower	174
6.2.1 Male Sterility and Fertility Restoration	176
6.2.2 Resistance to Downy Mildew	179
6.3 Candidate Gene Approach Based on Homology to Genes of Other Species	180
6.3.1 Herbicide Resistance in Sunflower	180

6.3.2 Genes Involved in Developmental Aspects in Sunflower	181
6.3.2.1 Embryogenesis and Plant Development	181
6.3.2.2 Non-dormancy	187
6.3.2.3 Pistil- and Pollen-specific Genes	188
6.3.3 Genes Involved in Abiotic Stress Responses	190
6.3.3.1 Heat Shock Proteins	190
6.3.3.2 Drought Related Genes	191
6.3.4 Disease Resistance	193
6.3.5 Quality Traits in Sunflower	195
6.3.5.1 Cloning Genes of Fatty Acid Biosynthesis	195
6.3.5.2 Cloning Genes Involved in Tocopherol Biosynthesis in Sunflower	197
6.4 Verification of Candidate Genes and Functional Analyses of Genes	199
6.4.1 Attempts of Functional Analyses by Transgenic Approaches in Sunflower	199
6.4.2 Use of Heterologous Systems to Analyze Genes Isolated from Sunflower	200
6.4.3 Mutant Analyses	202
6.4.3.1 Mutants in Fatty Acid Synthesis	202
6.4.3.2 Mutants in Developmental Processes	204
6.4.4 Site-directed Mutagenesis and Chimeric Constructs	205
6.5 Conclusions	206
References	207
7. Molecular Breeding	221
<i>Begoña Pérez-Vich and Simon T. Berry</i>	
7.1 Introduction	221
7.2 Overview of Components and Objectives for Molecular Breeding	222
7.3 Germplasm Characterization	224
7.4 Molecular Strategies to Create and Identify Novel Variation	227
7.5 Marker-assisted Selection	229
7.5.1 Marker Validation and Refinement	229
7.5.2 Assay Optimization	235
7.5.3 MAS in Sunflower Breeding Programs	236
7.5.3.1 Marker-assisted Gene Introgression	236
7.5.3.2 Gene Pyramiding	239
7.6 Molecular Breeding in Private Sector Breeding Programs	239
7.7 Limitations and Prospects of MAS	243
References	243

8. Oil Composition Variations	253
<i>André Bervillé</i>	
8.1 Introduction	253
8.1.1 Main Features of Lipids	254
8.1.2 Fatty Acids	255
8.1.3 The Role of Mutations to Unravel Fatty Acid Biosynthesis Pathways	256
8.1.4 Types of Mutation	257
8.1.5 Differences between Seed and Fruit Oils	258
8.2 Mutations Leading to One Main Fatty Acid Accumulated in Oil	258
8.2.1 Palmitic Acid	258
8.2.1.1 Palmitic Acid in Other Species	258
8.2.1.2 Palmitic Acid in Sunflower	259
8.2.1.3 Palmitoleic Acid	260
8.2.2 Stearic Acid	260
8.2.2.1 Stearic Acid in Other Species	260
8.2.2.2 Stearic Acid in Sunflower	260
8.2.3 Oleic Acid	261
8.2.3.1 Oleic Acid in Other Species	261
8.2.3.1.1 Cotton	262
8.2.3.1.2 Peanut	262
8.2.3.2 Oleic Acid in Sunflower	262
8.2.3.2.1 Biochemical Changes Induced by the Pervenets Mutation	263
8.2.3.2.2 Genetic Analysis of the HOAC Trait	263
8.2.3.2.3 Expression Induced Changes by Pervenets Mutation	264
8.2.3.2.4 DNA Changes Correlated with the Pervenets Mutation	265
8.2.3.2.5 A Model as the Pervenets Mutation Functions	268
8.2.3.2.6 Other Molecular and Biochemical Studies on the Pervenets Mutation	269
8.2.4 Linoleic and Linolenic Acids	270
8.2.4.1 Linoleic and Linolenic Acids in Other Species	270
8.2.4.2 Linoleic and Linolenic Acids in Sunflower	271
8.2.5 Wild Annual Sunflowers for Improving Oil Content and Quality in Cultivated Sunflower	271
8.3. Tocopherols	272
8.4. Phytosterols	273
Acknowledgements	274
References	274

9. Transgenic Sunflower	279
<i>Miguel Angel Cantamutto and María Mónica Poverene</i>	
9.1 Introduction	279
9.2 Released Transgenic Crops	283
9.3 Genetic Modification of Sunflower	284
9.3.1 Early Transformation Methods	284
9.3.2 General Procedures to Transform Sunflower	285
9.3.3 Intended Transgenic Sunflower Releases	287
9.4 Overcoming of Crop Constraints through Transgenic Sunflower and New Products	289
9.4.1 Low Soil Fertility	289
9.4.2 Weed Control	290
9.4.3 Pest Control	292
9.4.4 Disease Control	294
9.4.5 Novel Products	295
9.5 Debate about Transgenic Sunflower	296
9.6 Prospective View on Transgenic Sunflower Release	299
References	302
10. Future Prospects	313
<i>Brady A. Vick and Jinguo Hu</i>	
10.1 The Past	314
10.2 Future Potential to Increase Productivity	315
10.3 Impact of Advances in Sunflower Genomics	317
10.4 Future Potential to Expand into Other Geographical Areas	319
10.5 New uses	321
10.5.1 Biofuels and Lubricants	321
10.5.2 Bio-pharming by Sunflower	322
10.5.3 Bioremediation	323
10.6 Outlook	324
References	325
<i>Subject Index</i>	327