

Molecular Plant Breeding

Yunbi Xu



Contents

Preface	ix
Foreword by Dr Norman E. Borlaug	xv
Foreword by Dr Ronald L. Phillips	xvii
1 Introduction	1
1.1 Domestication of Crop Plants	1
1.2 Early Efforts at Plant Breeding	3
1.3 Major Developments in the History of Plant Breeding	4
1.4 Genetic Variation	9
1.5 Quantitative Traits: Variance, Heritability and Selection Index	10
1.6 The Green Revolution and the Challenges Ahead	16
1.7 Objectives of Plant Breeding	17
1.8 Molecular Breeding	18
2 Molecular Breeding Tools: Markers and Maps	21
2.1 Genetic Markers	21
2.2 Molecular Maps	43
3 Molecular Breeding Tools: Omics and Arrays	59
3.1 Molecular Techniques in Omics	59
3.2 Structural Genomics	68
3.3 Functional Genomics	81
3.4 Phenomics	91
3.5 Comparative Genomics	93
3.6 Array Technologies in Omics	100
4 Populations in Genetics and Breeding	113
4.1 Properties and Classification of Populations	113
4.2 Doubled Haploids (DHs)	116
4.3 Recombinant Inbred Lines (RILs)	131
4.4 Near-isogenic Lines (NILs)	138
4.5 Cross-population Comparison: Recombination Frequency and Selection	145
5 Plant Genetic Resources: Management, Evaluation and Enhancement	151
5.1 Genetic Erosion and Potential Vulnerability	152
5.2 The Concept of Germplasm	155

5.3	Collection/Acquisition	161
5.4	Maintenance, Rejuvenation and Multiplication	166
5.5	Evaluation	171
5.6	Germplasm Enhancement	186
5.7	Information Management	188
5.8	Future Prospects	192
6	Molecular Dissection of Complex Traits: Theory	195
6.1	Single Marker-based Approaches	197
6.2	Interval Mapping	202
6.3	Composite Interval Mapping	205
6.4	Multiple Interval Mapping	209
6.5	Multiple Populations/Crosses	214
6.6	Multiple QTL	217
6.7	Bayesian Mapping	219
6.8	Linkage Disequilibrium Mapping	223
6.9	Meta-analysis	233
6.10	<i>In Silico</i> Mapping	237
6.11	Sample Size, Power and Thresholds	239
6.12	Summary and Prospects	247
7	Molecular Dissection of Complex Traits: Practice	249
7.1	QTL Separating	249
7.2	QTL for Complicated Traits	258
7.3	QTL Mapping across Species	262
7.4	QTL across Genetic Backgrounds	264
7.5	QTL across Growth and Developmental Stages	270
7.6	Multiple Traits and Gene Expression	274
7.7	Selective Genotyping and Pooled DNA Analysis	277
8	Marker-assisted Selection: Theory	286
8.1	Components of Marker-assisted Selection	288
8.2	Marker-assisted Gene Introgression	293
8.3	Marker-assisted Gene Pyramiding	308
8.4	Selection for Quantitative Traits	318
8.5	Long-term Selection	327
9	Marker-assisted Selection: Practice	336
9.1	Selection Schemes for Marker-assisted Selection	337
9.2	Bottlenecks in Application of Marker-assisted Selection	339
9.3	Reducing Costs and Increasing Scale and Efficiency	344
9.4	Traits Most Suitable for MAS	350
9.5	Marker-assisted Gene Introgression	356
9.6	Marker-assisted Gene Pyramiding	363
9.7	Marker-assisted Hybrid Prediction	367
9.8	Opportunities and Challenges	378
10	Genotype-by-environment Interaction	381
10.1	Multi-environment Trials	383
10.2	Environmental Characterization	386
10.3	Stability of Genotype Performance	394
10.4	Molecular Dissection of GEI	402

10.5	Breeding for GEI	410
10.6	Future Perspectives	414
11	Isolation and Functional Analysis of Genes	417
11.1	<i>In Silico</i> Prediction	419
11.2	Comparative Approaches for Gene Isolation	426
11.3	Cloning Based on cDNA Sequencing	431
11.4	Positional Cloning	435
11.5	Identification of Genes by Mutagenesis	441
11.6	Other Approaches for Gene Isolation	454
12	Gene Transfer and Genetically Modified Plants	458
12.1	Plant Tissue Culture and Genetic Transformation	458
12.2	Transformation Approaches	461
12.3	Expression Vectors	468
12.4	Selectable Marker Genes	473
12.5	Transgene Integration, Expression and Localization	480
12.6	Transgene Stacking	487
12.7	Transgenic Crop Commercialization	492
12.8	Perspectives	499
13	Intellectual Property Rights and Plant Variety Protection	501
13.1	Intellectual Property and Plant Breeders' Rights	502
13.2	Plant Variety Protection: Needs and Impacts	504
13.3	International Agreements Affecting Plant Breeding	509
13.4	Plant Variety Protection Strategies	518
13.5	Intellectual Property Rights Affecting Molecular Breeding	524
13.6	Use of Molecular Techniques in Plant Variety Protection	535
13.7	Plant Variety Protection Practice	541
13.8	Future Perspectives	543
14	Breeding Informatics	550
14.1	Information-driven Plant Breeding	550
14.2	Information Collection	554
14.3	Information Integration	562
14.4	Information Retrieval and Mining	568
14.5	Information Management Systems	572
14.6	Plant Databases	579
14.7	Future Prospects for Breeding Informatics	595
15	Decision Support Tools	599
15.1	Germplasm and Breeding Population Management and Evaluation	600
15.2	Genetic Mapping and Marker–Trait Association Analysis	605
15.3	Marker-assisted Selection	613
15.4	Simulation and Modelling	615
15.5	Breeding by Design	621
15.6	Future Perspectives	623
	References	627
	Index	717