
Contents

1	Introduction – Genetics of Tropical Forests	1
Part A	Genetic Processes in Tropical Forests	3
2	Population Genetics – an Overview	5
2.1	Introduction	5
2.2	The Population	5
2.3	Variation at Gene Loci	6
2.3.1	The Molecular Basis of Genetic Variation	6
2.3.1.1	Molecular Markers	7
2.3.1.2	Biochemical Markers – Isozymes	12
2.3.2	The Gene As a Unit of Heredity	13
2.3.3	The Mode of Inheritance	14
2.3.4	Definition and Classification of Gene Markers	15
2.4	Genetic Structures Within Populations	16
2.4.1	Allelic and Genotypic Structures	16
	Example 2.1: Genetic Structures at an Isozyme Gene Locus in <i>Dalbergia sissoo</i>	17
2.4.2	Variation at Uniparentally Inherited Markers	18
	Example 2.2: Diversity of cpDNA Haplotypes in <i>D. sissoo</i>	18
2.5	Evolution and Evolutionary Factors	19
2.6	Phenotypic Variation	21
2.7	Recommended Literature	22
3	Genetic Variation of Tropical Forest Plants	23
3.1	Introduction	23
3.2	Genetic Inventories	23
3.3	Measurement of Genetic Variation	24
3.3.1	Genetic Variation Within Populations	24
3.3.1.1	Genetic Multiplicity	25
3.3.1.2	Genetic Diversity	25
3.3.2	Genetic Differentiation Among Populations	27
3.3.2.1	Genetic Distances	27
3.3.2.2	Genetic Differentiation	27

3.4	Genetic Variation in Tropical Forest Species – General Trends	28
3.5	Case Studies on Genetic Variation Patterns	31
	Example 3.1: Genetic Variation at Isozyme Gene Loci in Natural Populations of <i>Acacia auriculiformis</i>	31
	Example 3.2: Genetic Differentiation Among Populations of <i>Eugenia dysenterica</i> from the Brazilian Cerrado	33
	Example 3.3: Genetic Variation of <i>Swietenia macrophylla</i> Across the Brazilian Amazon	33
	Example 3.4: Genetic Variation of Endangered Australian Species of the Genus <i>Fontainea</i> Assessed with RAPD Markers and by DNA Sequences	34
	Example 3.5: Genetic Variation of <i>Shorea leprosula</i> and <i>Shorea parvifolia</i> in Indonesia Assessed at AFLP Loci	35
	Example 3.6: Genetic Variation of <i>Cedrela odorata</i> at cpDNA	37
3.6	Recommended Literature	39
4	Sexual and Asexual Reproduction in Tropical Forests	41
4.1	Introduction	41
4.2	Sexual Reproduction	41
4.2.1	Sexual Types and Sexual Systems	42
4.2.2	Sexual Systems	44
4.2.3	Sexual Structures and Sexual Function	47
4.3	Asexual Reproduction	49
4.3.1	Vegetative Reproduction	50
4.3.2	Apomixis	51
4.4	Recommended Literature	52
5	Gene Flow and Migration	53
5.1	Introduction	53
5.2	Gene Flow Through Pollen	54
5.2.1	Pollination and Fertilization	54
5.2.2	Pollen Vectors in Tropical Forests	54
5.2.2.1	Pollination by Wind (Anemogamy)	54
5.2.2.2	Pollination by Animals (Zoogamy)	55
5.2.3	Pollen Dispersal Assessed by Marker-Based Studies	60
5.2.3.1	Dispersal of Rare Alleles	60
	Example 5.1: Gene Dispersal in a Clonal Seed Orchard of Teak (<i>Tectona grandis</i>)	60
5.2.3.2	Paternity Analyses	61
	Example 5.2: Gene Flow Through Pollen in <i>Neobalanocarpus</i> <i>heimii</i> and <i>Dipterocarpus tempehes</i> (Dipterocarpaceae)	62
	Example 5.3: Pollen Dispersal in Three Neotropical Tree Species with Different Spatial Distribution Patterns on Barro Colorado Island	63

5.2.3.3	Model-Based Estimates of Pollen Dispersal	64
	Example 5.4: Pollen Dispersal in <i>Dinizia excelsa</i> (Fabaceae)	64
5.2.4	Efficiency of Pollen Vectors for Gene Flow	65
5.3	Migration of Seeds	65
5.3.1	Seed Vectors	65
5.3.1.1	Abiotic Seed Dispersal	65
5.3.1.2	Biotic Seed Dispersal	66
5.3.2	Efficiency of Seed Dispersal	66
5.4	Long-Distance Gene Flow and Migration in Tropical Forest Species	67
5.5	Recommended Literature	68
6	Mating Systems	69
6.1	Introduction	69
6.2	Random Mating and Panmixis	70
6.2.1	Heterogeneity of Pollen Allele Frequencies	70
6.2.2	Panmixis and Hardy–Weinberg Structures	72
6.3	Selfing and Outcrossing Rates	73
6.3.1	Estimates of Selfing Rates Based on Rare Alleles	74
	Example 6.1: Estimates of Selfing Rates in Teak (<i>Tectona grandis</i>) Populations	74
6.3.2	Estimates of Selfing Rates Based on a Mixed Mating Model	76
6.3.3	Estimates of Selfing Rates Based on Nonmaternal Alleles	76
6.4	Inbreeding and Inbreeding Depression	78
6.4.1	Genetic Consequences of Inbreeding	78
6.4.2	Inbreeding Depression	80
	Example 6.2: Inbreeding Depression in Eucalypts	80
6.5	Incompatibility and Self-Sterility	82
6.5.1	Incompatibility	82
6.5.2	Self-Sterility	84
6.6	Environmental Effects on Mating	84
6.7	Recommended Literature	85
7	Adaptation and Coevolution	87
7.1	Introduction	87
7.2	Physiological and Evolutionary Adaptation	87
	Example 7.1: Viability Selection During Early Life Stages of <i>Platypodium elegans</i>	89
7.3	Species Interactions and Coevolution	90
	Example 7.2: Figs and Their Pollinators	91
7.4	Recommended Literature	97
8	Phylogenies and Evolution Above the Species Level	99
8.1	Introduction	99
8.2	The Evolution of Species Diversity in the Tropics	99

8.2.1	Species Diversity in Tropical Forests	99
8.2.2	Evolution Above the Species Level	101
8.3	Molecular Phylogenies	102
	Example 8.1: A Molecular Phylogeny of Indonesian Dipterocarpoideae	103
	Example 8.2: Evolution of the Genus <i>Inga</i>	104
8.4	Recommended Literature	106
Part B	Applications of Genetics to Tropical Forestry	109
9	Fragmentation of Forests	111
9.1	Introduction	111
9.2	The Genetic Status of Fragmented Tree Populations	113
	Example 9.1: Genetic Impact of Fragmentation on a Rain Forest Canopy Tree	116
	Example 9.2: Connectivity of Population Fragments of a Medium-Sized Dry-Forest Tree	119
9.3	Genetic Preconditions for Restoration and Persistence	123
9.4	Recommended Literature	127
10	Genetic Aspects of the Management of Natural Tropical Forests	129
10.1	Introduction	129
10.2	Selective Logging	130
10.2.1	Effective Population Density After Logging	131
10.2.2	The Question of Dysgenic Selection	135
10.3	Natural Regeneration	136
10.4	Genetic Aspects of the Manipulation of Dynamic Processes in Natural Forests	137
10.5	Genetic Aspects of Sustainability in Natural Tropical Forests	140
10.6	Recommended Literature	146
11	Provenance Research	147
11.1	Introduction	147
11.2	Definitions	148
11.3	Historical Development	150
11.4	Provenance Tests	151
11.4.1	Types of Field Experiments in Provenance Research	153
11.4.2	Traits Studied in Field Trials	155
11.4.3	Design, Conduct, and Analysis of Provenance Trials	156
11.4.3.1	Collection of Material for Provenance Trials	156
11.4.3.2	Production of Planting Stock	159
11.4.3.3	Experimental Design	159

11.4.3.4	Choice of Experimental Sites	161
11.4.3.5	Number and Distribution of Locations of an Experimental Series	162
11.4.3.6	Observation Period of Field Experiments	163
11.5	Provenance Differentiation and Geographic Variation Pattern	163
11.6	Choice of Provenances in Tropical Forestry	165
	Example 11.1: Provenances of <i>Eucalyptus camaldulensis</i> and Their Growth Performance	169
	Example 11.2: International Provenance Trials in Teak (<i>Tectona grandis</i>)	170
11.7	Recommended Literature	172
12	Domestication and Breeding of Tropical Forest Trees	173
12.1	Introduction	173
12.2	Domestication	174
12.3	Genetic Controlledness of Phenotypic Traits	176
12.3.1	Individuals Related by Descent	176
12.3.2	Pair Comparisons in the Field	177
12.3.3	Response to Natural Viability Selection	179
12.4	Linear Model of Genetic Effects on a Phenotypic Trait	179
12.4.1	Phenotypic Trait Expressions	179
12.4.2	Genetic Variance Components and Heritability	182
12.5	Estimation of Breeding Parameters; Progeny Testing	183
12.5.1	Progenies of Open-Pollinated Trees	183
12.5.2	Progeny Tests After Controlled Pollination	184
12.6	Methods of Selection	186
12.6.1	Selection of Plus Trees	187
12.6.2	Selection in Progeny Tests	188
12.6.3	Selection of Clones	189
12.6.4	Marker-Assisted Selection	189
12.7	Heterosis Breeding in Forest Trees	192
	Example 12.1: Breeding Eucalypts in Aracruz, Brazil	194
12.8	Propagation of Breeding Products	196
12.8.1	Clonal Seed Orchards	196
	Example 12.2: Clonal Seed Orchards of Teak (<i>Tectona grandis</i>)	198
12.8.2	Seedling Seed Orchards	201
12.8.3	Mass Multiplication of Clones	204
12.9	Multiple Population Breeding	205
12.10	Breeding Strategy	207
12.11	Genetic Consequences of Domestication and Breeding	209
12.11.1	General Considerations	209
12.11.2	Monitoring of Breeding Projects by Use of Genetic Markers	210
12.12	Recommended Literature	211

13	Genetic Aspects of Plantation Forestry in the Tropics	213
13.1	Introduction	213
13.2	Plantations of Exotic Tree Species	215
	Example 13.1: The Origin of Early Plantations of <i>Acacia mangium</i> in Sabah	217
13.3	Plantations of Indigenous Species	218
13.4	Basic and Reproductive Material	220
13.5	Production and Collection of Seed	222
13.5.1	Seed Production Areas	222
13.5.2	Provenance Resource Stands	223
13.5.3	Seed Orchards	224
13.6	Collection and Storage of Seed	226
13.7	Planting Stock Production	227
13.7.1	Seedlings	227
13.7.2	Clonal Multiplication	228
13.8	Establishment and Development of Plantations	229
13.9	Natural Regeneration of Plantations	230
13.10	Use of Breeding Products	231
13.11	Recommended Literature	235
14	Conservation of Genetic Resources in Tropical Forest Trees	237
14.1	Introduction	237
14.2	Development of Tree-Conservation Genetics	239
14.3	Defining Priorities	240
14.4	Conservation Objectives	241
14.4.1	Objective 1: Preservation of the Potential for Particular Trait Expressions	241
14.4.2	Objective 2: Preservation of Maximum Variation	242
14.4.3	Objective 3: Preservation of Adaptability	243
14.5	Selection of Genetic Resources	243
14.5.1	Inventory of Genetic Marker Loci	245
14.5.2	Inventory of Adaptive Trait Expressions and Adaptive Markers	247
14.6	Conservation Methods	250
14.6.1	Dynamic Conservation in Situ	251
14.6.2	Dynamic Conservation ex Situ in Man-Made Forests	253
14.6.3	Conservation of Seeds in Gene Banks	255
14.6.4	Vegetative Propagation for the Conservation of Forest Genetic Resources	256
14.6.5	Biotechnological Methods of Preservation	256
14.7	Regeneration of Forest Genetic Resources	257
	Example 14.1: Conservation of the Genetic Resources of <i>Pinus merkusii</i> in Thailand	259
14.8	Programs for the Protection of Forest Genetic Resources	264
14.9	Recommended Literature	265
	References	267
	Index	307