

Dharam P. Abrol

Pollination Biology

Biodiversity Conservation
and Agricultural Production

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Foreword

We dwell in the midst of yet another world food shortage that exacerbated by escalating prices the world over. Coupled to the apparent instability of climate cycles in recent years, one-fourth of our growing human population is fast approaching famine. Concomitantly, this situation includes rampant declines in honeybee populations across three continents, for as yet incompletely resolved reasons, and with no remedy or end in sight. These problems have been further aided and abetted by a lack of prophylactic progress in the conservation of biodiversity and increased agricultural production.

The above notwithstanding, there has been no shortage of interest in studies on honeybees in relation to pollination. Indeed, a brief perusal of this subject at the website Google scholar shows that during the last century the publication of research papers in this area has grown exponentially, and in just the last decade, some 15,000 items have appeared. In the event, it is both fair and pertinent to ask: “Is there actually need for yet another work on pollination biology, the conservation of biodiversity, and agricultural production”?

The answer depends on whether we are after the analysis, perhaps in great detail, of a particular aspect of a system; or seek a holistic treatise concerned with complete systems within a social human context. For the former, there are several excellent, scholarly works available. Works of the latter kind are few and far between. The present tome “Pollination biology – Biodiversity conservation and agricultural production” is of the latter kind. This work originates in the Himalayan region where agriculturalists have pioneered practical studies in pollination that combine basic ideas rooted in three facets: biological conservation, rural development and increased agricultural production and the role of pollination in improving food security and livelihoods.

Professor Abrol develops the theme that pollination is basic to agricultural and natural productivity and that this is an ancient co-evolved and intricate process involving animals and plants in mutualisms. The value of pollination to agriculture is of great and inestimable value in the global economy of *Nature*. Indeed, pollination is essential for sexual reproduction in plants and their seed and fruit sets.

These can be increased considerably in areas where there is a dearth of natural pollinators by introducing pollinators, a practice that has yielded excellent results.

The value of bees in pollination is undisputed. Nonetheless, Abrol evaluates systems for maintaining honeybees on crops that are insect-pollinated. Factors that attract honeybees to flowers, floral competition, and methods for increasing numbers of pollen and nectar foragers as well as techniques for attracting honey bees to, and retaining them on, target crops are fully probed. Wild bees provide pollination services that often go unnoticed, yet are critical to the success of some forms of agriculture. The impact that bees have on our food production systems should serve as a reminder to our dependence, in general, on the ecosystems around us.

Against this, on the one hand the use of pesticides for pest control and the role of honeybees for crop pollination on the other have become essential components of modern agriculture and without either global food production would be seriously impaired. Unfortunately, these two practices are not always compatible, as honeybees are susceptible to many commonly used chemicals for the control of insect pests. The major constraint confronting pollinator-plant interactions is the indiscriminate and excessive use of pesticides for controlling insect pests. Moreover, reduction in the population of these beneficial insects due to insecticides incurs significant environmental, ecological and economic costs.

The energetics of these systems is rather interesting. Pollinators are highly selective in their floral visits and choose those flowers which best meet their energetic needs. The energy needs and foraging dynamics of pollinators are dependent upon prevailing weather conditions which regulate the schedule of activities thus influencing the energy budget. Much of Professor Abrol's own research has been on the role of energetics in pollinator-plant interactions and indicates directions for future lines of research for the enhanced understanding of pollination biology. Energetic costs of pollination have been ameliorated by the *Evolution* of plant volatile production in pollination ecology and in pollinator-plant relationships are reviewed here. This interrelationship between the two is governed by biochemical factors such as scent, colour and nutritional value of nectar and pollen.

Pollinators and pollination are crucial in the functioning of almost all terrestrial ecosystems including those dominated by agriculture because they are in the front line of sustainable productivity through plant reproduction. But, any programmes specifically focused on pollination require formal education at all levels as well as informal capacity building amongst farmers, land managers, policy makers and other target groups, including the public as a whole. This is, indeed, an awesome task and we must congratulate Professor Abrol for this uncommon blend of pure and applied science placed in the broader human social context.

Grahamstown, South Africa

Randall Hepburn

Preface

Pollen, the small spore, plays an important role in the sexual reproduction of angiosperms as does the sperm in the animals. However, the pollen grains are non-motile requiring some foreign agent for their carry over to the female counter part. Wind, water and gravity are some of the abiotic agents, but through them the pollen carryover is undirected and very large number of pollen has to be produced to ensure successful pollination. Still the effectivity of pollination by these agents is low. On the other hand in a large number of plant species, pollination is effected by the bioagents. This is especially true in plants exhibiting self-incompatibility, protandry or protogyny. Pollination by bees and birds is of special importance. Efficiency of pollination by bioagents is the direct measure of mutualism specialization which is reflected in terms of success of reproduction as evidenced by quality and quantity of produced seeds/fruits. Higher the degree of mutualism, specialization more should be interdependence between the two participating organism – the plants and the pollinators. The extermination of one would adversely affect the survival and/or propagation of the other. In other words, loss of pollinators should mean decline in the reproductive propagation of several cross-pollinated plant species including reduction in crop seed production. Conversely, conservation of several plant species and increase in seed production of cross-pollinated crops could be ensured by the conservation of natural pollinators and vice-versa.

During the past four decades, human population has increased more than two folds exerting a tremendous pressure on the natural resources and the land especially for food, fuel and timber. As a consequence, vast forests have been converted into agricultural land and mountains have become barren due to ruthless cuttings and grazing, thus extensively destroying the food and habitat of several pollinators species. Along with these, use of chemicals, too, have greatly wiped out the population of natural pollinators, thus resulting in failure of reproduction in several cross-pollinated plant species including the agricultural crops. This book on pollination biology addresses two basics questions. How the pollination can be utilized in the (1) conservation of plant species and (2) for crop seed/fruit production. The various aspects related to pollination, plant reproduction, pollinators behaviour, ecology and management and their safety are discussed to serve as guide to evolve future strategies for sustainable agriculture without disturbing the environment and the natural balance.

The land resources are being limited and increased agricultural production is to be obtained through intensive farming i.e. higher cropping intensity, better seed and greater use of fertilizers. New cropping patterns are likely to create new problems, new pests may appear or pests now considered minor may become major. In some crops, any amount of fertilizer, irrigation or pesticide use may not even yield a fraction of yield unless pollinated by bees. Honeybees play an important role in the pollination of large portion of the angiosperms of the world and maintain natural vegetation needed for survival of the ecosystems and the world as whole. The magnitude and direction of all manner of anthropogenic global environmental change have lately come to dominate the conversation at national/international levels and the debate is raging over the validity of various projections of consequences and diverse proposals for remediation. Of the multitude of ways humans could be harming the planet, however, one that has largely been ignored is the “pollinator crisis” – the perceived global decline in the number and viability of animal species that facilitate reproduction of flowering plants, the overwhelming majority of plants in terrestrial communities. In her hugely influential book *Silent Spring* published more than 50 years ago, Rachel Carson recognized the central role of pollinators. They are the proverbial birds and the bees, along with many other insect species and even a handful of mammals that maintain human health and terrestrial biodiversity. Carson painted a bleak picture of a world with “fruitless falls”. In the intervening decades, reports have quietly accumulated from virtually every continent of shortages or extinction of pollinators of various descriptions. Ironically, despite its apparent lack of marquee appeal, pollinator decline is one form of global change that actually does have credible potential to alter the shape and structure of the terrestrial world. Over the past decade, the public has begun to take notice and ask whether a pollinator crisis is brewing and, if so, what can be done to avert it.

The book emphasizes conserving and culturing honey bees, non-Apis bees and pollinators other than bees. It also addresses the biology of pollination and managing bees for optimum crop pollination. Individual pollination requirements and recommendations for some of the most important crops are discussed. The book has a unique blend of basic and applied science to understand the pollination biology in a much wider context.

The writing of this book has been possible with the active help and support of a wide spectrum of people has helped in one way or the other. This book is outcome of my personal experiences and the contributions of several workers which have been incorporated. I express my humble and profound thank to all of them whose hard work has enabled me to compile the suitable information in a such a manner that it would be useful to those interested in basic and applied aspects of pollination biology. The illustrations and figures are either original or redrawn from other sources which have been cited individually in the figure legends. All the authors whose work has been used/refereed deserve special appreciation and heartiest acknowledgments.

I am particularly indebted to Professor Dr. Raghavendra Gadagkar, Centre for Ecological Sciences, Indian Institute of Sciences Bangalore for his help, guidance and encouragement. I also thank my university authorities for the excellent working atmosphere and needed encouragement for compiling such a voluminous book.

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Jammu

Dharam P. Abrol

Contents

1	Introduction	1
1.1	Introduction.....	1
1.2	Role and Importance of Pollinators	9
1.3	Barriers to Self-Fertilization	9
1.4	Pollinators in Natural and Agricultural Ecosystems.....	11
1.5	Population Management of Pollinators.....	13
1.6	Value of Pollination.....	15
1.7	Pollination Crisis.....	16
	References.....	18
2	Historical Perspective	25
2.1	Development of the Knowledge of Plant Pollination	25
	References.....	33
3	Pollination – Basic Concepts	37
3.1	Introduction.....	37
3.2	Types of Pollination	38
3.2.1	Self Pollination.....	38
3.2.2	Auto-Pollination.....	38
3.2.3	Cross-Pollination.....	38
3.2.4	Self Fruitful.....	39
3.2.5	Self Unfruitful or Self in Compatible	39
3.2.6	Cross Fruitful Varieties	39
3.2.7	Cross Unfruitful or Incompatible Varieties.....	39
3.2.8	Monoecious Plants	39
3.2.9	Dioecious Plants.....	40
3.2.10	Gynoecious Plants	40
3.3	Flower Structure.....	40
3.3.1	Nectaries and Nectar Secretion.....	42
3.3.2	Stigma Receptivity	42
3.3.3	Pollination and Pollenizer	43

- 3.4 Pollination and Fertilization..... 44
- 3.5 Pollinating Agents..... 44
 - 3.5.1 Biotic Pollination 44
 - 3.5.2 Abiotic Pollination..... 45
 - 3.5.3 Abiotic Vectors..... 45
 - 3.5.4 Biotic Vectors..... 47
- 3.6 Why Is Cross-Pollination Important? 48
- 3.7 Attractants and Rewards for Biotic Pollinators..... 49
- 3.8 Pollination Syndromes 53
- References..... 53
- 4 Applied Pollination: Present Scenario 55**
 - 4.1 Introduction..... 55
 - 4.2 Pollination of Fruit Crops 56
 - 4.2.1 Almond 56
 - 4.2.2 Apricot 56
 - 4.2.3 Apple..... 56
 - 4.2.4 Cherry 59
 - 4.2.5 Carambola..... 59
 - 4.2.6 Coconut..... 60
 - 4.2.7 Grape..... 60
 - 4.2.8 Jujube..... 60
 - 4.2.9 Litchi..... 60
 - 4.2.10 Loquat 61
 - 4.2.11 Mango 61
 - 4.2.12 Muskmelon 62
 - 4.2.13 Papaya..... 62
 - 4.2.14 Passion Fruit 62
 - 4.2.15 Kiwifruit (*Actinidia deliciosa*)..... 62
 - 4.2.16 Peach..... 62
 - 4.2.17 Pear 63
 - 4.2.18 Persimmon 63
 - 4.2.19 Strawberry..... 64
 - 4.2.20 Watermelon..... 64
 - 4.3 Pollination of Vegetable Crops 64
 - 4.3.1 Cucumber..... 64
 - 4.3.2 Carrot 65
 - 4.3.3 Cole Crops 65
 - 4.3.4 Eggplants 66
 - 4.3.5 Okra 66
 - 4.3.6 Onion 66
 - 4.3.7 Pumpkin..... 67
 - 4.3.8 Radish and Turnip..... 67
 - 4.3.9 Vegetable Sponge and Ribbed Gourd 67
 - 4.3.10 White Flower Gourd 68

4.4	Oilseed Crops.....	68
4.4.1	Cruciferous Oilseeds.....	68
4.4.2	Flax.....	69
4.4.3	Niger.....	69
4.4.4	Oil-Palm.....	70
4.4.5	Peanut.....	70
4.4.6	Sesame.....	70
4.4.7	Sunflower.....	70
4.5	Pollination of Forage Crops.....	71
4.5.1	Alfalfa.....	71
4.5.2	Berseem.....	71
4.5.3	Vetch.....	72
4.6	Pollination of Fibre Crops.....	72
4.6.1	Cotton.....	72
4.6.2	Kenaf.....	73
4.6.3	Sunhemp.....	73
4.7	Pollinators of Pulses Crops.....	73
4.7.1	Pigeon Pea.....	73
4.8	Pollination of Spices, Condiments and Beverages etc.....	74
4.8.1	Cacao.....	74
4.8.2	Cardamom.....	74
4.8.3	Chicory.....	74
4.8.4	Fennel, Coriander and Cumin.....	74
4.8.5	Tea.....	75
	References.....	75
5	Honeybee and Crop Pollination.....	85
5.1	Introduction.....	85
5.2	Honeybee's Adaptations as Pollinators.....	86
5.3	Benefits of Honeybee Pollination.....	87
5.4	Honeybees and Pollination.....	88
5.4.1	Constancy.....	88
5.4.2	Thoroughness.....	88
5.4.3	Working Hours.....	88
5.4.4	Total Population.....	89
5.5	Honeybees as the Most Efficient and Manageable Pollinators.....	89
5.6	Pollination Behavior of Honeybees.....	93
5.7	Factors Affecting Bee Populations.....	93
5.8	Manipulate Bees for Crop Pollination.....	94
5.9	Protecting Bees from Pesticides.....	94
5.10	Minimum Colony Strength.....	95
5.11	Value of Bee Pollination to Agriculture.....	95
5.12	Unmeasured Pollination Benefits.....	95
5.13	Honeybees as Pollinators.....	96

- 5.14 Management of Honeybees for Pollination 96
 - 5.14.1 Foraging Strength of Colonies 96
 - 5.14.2 Pollination Requirement and Concentration of Colonies..... 96
 - 5.14.3 Foraging Efficiency of Colonies and Their Distance from the Crop 98
 - 5.14.4 Moving Colonies to Crops 98
 - 5.14.5 Time of Moving Colonies on Crops..... 99
 - 5.14.6 Replacement or Rotation..... 99
 - 5.14.7 Temporary Placement 99
 - 5.14.8 Removing Floral Competition 99
 - 5.14.9 Pollen Dispensers..... 100
 - 5.14.10 Disposable Pollination Units (DPU’s) 100
 - 5.14.11 Arrangement of Colonies 100
- 5.15 Evaluating Honeybee Colonies for Pollination..... 100
 - 5.15.1 Colony Size and Efficiency 101
 - 5.15.2 Management of the Colonies 101
 - 5.15.3 Amount of Comb 102
 - 5.15.4 Amount of Brood 102
 - 5.15.5 Number of Bees 102
 - 5.15.6 Food Requirement..... 102
- 5.16 Challenges in Managed Crop Pollination 102
- 5.17 Management During Pollination..... 104
- 5.18 Management of Bee Pollination of Crops..... 107
- References..... 108

- 6 Wild Bees and Crop Pollination 111**
 - 6.1 Management of Wild Bees for Pollination 111
 - 6.2 Value of Wild Bees as Pollinators..... 113
 - 6.3 Diversity of Wild Bees..... 113
 - 6.4 Why Wild Bees Management 115
 - 6.5 Diversity of Bees in India 120
 - 6.5.1 Family Stenotritidae Cockerell 126
 - 6.5.2 Family Colletidae Lepeletier..... 126
 - 6.5.3 Family Andrenidae Latreille 127
 - 6.5.4 Family Halictidae Thomson..... 128
 - 6.5.5 Family Melittidae Schenck 129
 - 6.5.6 Family Megachilidae Latreille 129
 - 6.5.7 Family Apidae Latreille 132
 - 6.6 Alkali Bees..... 134
 - 6.7 Leafcutter Bees 134
 - 6.7.1 Nesting Materials and Shelters 135
 - 6.8 Carpenter Bees 137
 - 6.8.1 Future Prospects of Carpenter Bees 137

- 6.9 Other Bees..... 138
 - 6.9.1 Stingless Bees 138
 - 6.9.2 Stingless Bees Are Better Pollinators Why?..... 140
 - 6.9.3 Floral Preference 141
 - 6.9.4 What Makes a Stingless Bee a Good Pollinator?..... 141
 - 6.9.5 Crop Pollination 143
 - 6.9.6 Pollination of Non-crop Species 145
 - 6.9.7 Advantages of Stingless Bees over Honey Bees..... 145
 - 6.9.8 Disadvantages of Stingless Bees..... 146
- 6.10 Bumblebees..... 146
 - 6.10.1 The Distribution and Diversity of Bumblebee in the World 147
 - 6.10.2 Effectiveness of Bumble Bees and Honey Bees as Pollinator 148
 - 6.10.3 Bumble Bee Foraging Activity 152
 - 6.10.4 Foraging Activity on Different Crops Grown in Polyhouse 152
 - 6.10.5 Life Cycle..... 153
 - 6.10.6 Foraging and Constancy..... 154
 - 6.10.7 Efficiency 156
 - 6.10.8 Pollinator Effectiveness 156
 - 6.10.9 Colony Characters and Development..... 157
 - 6.10.10 What Are Cuckoo Bumblebees?..... 157
 - 6.10.11 Domestication of Bumble Bees 157
 - 6.10.12 Bumblebee for Pollination of Crop..... 159
 - 6.10.13 Communication..... 160
 - 6.10.14 Profit and Loss 160
 - 6.10.15 Scent Marking Visited Flowers..... 160
 - 6.10.16 Distances Flown..... 161
 - 6.10.17 Foraging Preferences..... 161
 - 6.10.18 Nest Searching by Queens 161
 - 6.10.19 Natural Enemies 162
 - 6.10.20 Advantages of the Use of Bumblebees 162
 - 6.10.21 Applications 163
 - 6.10.22 Key Benefits..... 164
- 6.11 Role of Non Apis Bees in Crop Pollination..... 165
 - 6.11.1 Pollination in Alfalfa..... 168
 - 6.11.2 Other Crops..... 169
- 6.12 Non-Apis Bees and Future Prospects 170
- References..... 172
- 7 Value of Bee Pollination..... 185**
 - 7.1 Introduction..... 185
 - 7.2 Indirect Impacts of Pollination..... 186
 - 7.3 Pollinating Agents..... 188

7.4	Economics of Plant Pollination.....	189
7.5	Signs of Inadequate Pollination	190
7.6	Ecological Relationships.....	190
7.7	Commercial Pollination Potentials	191
7.8	Impact of Pollinators on World Crops	194
7.9	Use of Other Bees for Pollination.....	198
7.10	The Value of Honeybee Pollination Services.....	201
	7.10.1 Unmeasured Pollination Benefits.....	202
7.11	Economic Value of Insect Pollination.....	207
7.12	Monetary Losses in Crop Yields Due to Decline of Pollinators	208
7.13	Economic Valuation of Bee Pollination Services	208
7.14	Environmental Economics and Its Application to Pollination Services	214
7.15	Methods for the Valuation of Pollination Services	214
7.16	Constraints to Valuation of Pollination Services.....	215
7.17	Results of Existing Pollination Services Valuation Studies.....	215
7.18	Conclusions and Ways Forward.....	217
	References.....	218
8	Planned Honeybee Pollination for Crop Production	223
8.1	Introduction.....	223
8.2	Management of Honey Bees for Pollination.....	224
8.3	Honey Bees as Pollinators	225
	8.3.1 Domesticated Species	225
	8.3.2 Wild Species	225
	8.3.3 Non-Apis Bees	225
	8.3.4 Stingless Bees	226
8.4	Management of Honey Bees for Pollination.....	226
	8.4.1 Foraging Strength of Colonies	226
	8.4.2 Pollination Requirement and Concentration of Colonies	226
	8.4.3 Foraging Efficiency of Colonies and Their Distance from the Crop	227
	8.4.4 Moving Colonies to Crops	228
	8.4.5 Time of Moving Colonies on Crops.....	228
	8.4.6 Arrangement of Colonies	228
	8.4.7 Effect of Weather	229
	8.4.8 Directing Bees to Crops	229
	8.4.9 Increasing the Attractiveness of Crops	230
	8.4.10 Increasing the Proportion of Pollen Gatherers.....	230
	8.4.11 Using Man-Made Devices to Increase Pollination	230
	8.4.12 Use of Synthetic Pheromones	231
	8.4.13 Floral Attractants and Floral Competition	231
	8.4.14 Increasing the Numbers of Pollen and Nectar Collectors.....	231

8.4.15	Attractants and Sprays	232
8.4.16	Sprays.....	235
8.4.17	Selection and Breeding of Honey Bees.....	236
8.4.18	Management of Honey Bee Colonies	237
8.4.19	Other Methods	239
8.4.20	Pollen Compatibility and Pollinating Fruit Crops	241
8.4.21	Orchard Planting Patterns	241
8.4.22	How Are Hive Bees Used for Pollination Management?.....	242
8.5	Managing Pollination of Crops Secreting a Good Amount of Nectar and Pollen and Having a Long Blooming Period	242
8.5.1	Fruit Crops	242
8.5.2	Vegetable Crops and Vegetable-Seed Crops	249
8.5.3	Oilseed Crops.....	252
8.5.4	Spices	254
8.6	Conclusions and Future Research	255
	References.....	256
9	Non Bee Pollinators-Plant Interaction	265
9.1	Introduction.....	265
9.2	Biotic Vectors.....	266
9.2.1	Coleoptera	269
9.2.2	Diptera.....	269
9.2.3	Flies as Flowers.....	270
9.2.4	Pollination by Butterflies (Psychophily).....	273
9.2.5	Pollination by Moths (Phalaenophily)	273
9.2.6	Pollination by Thrips.....	274
9.2.7	Pollination by Birds (Orinthophily).....	281
9.2.8	Fly and Beetle Pollination (Myophily and Cantharophily)	286
9.2.9	Ants and Pollination (Myrmecophily)	287
9.2.10	Pollination by Wasps (<i>Sphēcophily</i>).....	288
9.3	Pollination by Other Invertebrates	290
9.3.1	Pollination by Snails	290
9.3.2	Pollination by Vertebrates.....	291
9.4	Bats and Their Flowers	293
9.5	Non-flying Mammals as Pollinators	296
9.6	Monkeys as Pollinators	297
9.7	Nonflying Mammals	297
9.7.1	Nonflying Mammals	297
9.8	Contemporary Relationships.....	299
9.8.1	Marsupials (Metatherophily)	300
9.8.2	Rodents (Sminthophily)	300
9.8.3	Pollination by Squirrels.....	300
9.8.4	Pollination by Lizards.....	301
	References.....	304

10 Safety of Pollinators	311
10.1 Introduction.....	311
10.2 Factors Influencing Bee Poisoning.....	315
10.2.1 Pesticide Formulation.....	316
10.2.2 Selectivity of Pesticides.....	316
10.2.3 Period of Application.....	316
10.2.4 Time of Application.....	317
10.2.5 Attractiveness of Crop.....	317
10.2.6 Weather.....	317
10.2.7 Temperature.....	317
10.2.8 Method of Application.....	317
10.2.9 Colony Strength.....	318
10.2.10 Age and Body Size of Honeybees.....	318
10.2.11 Distance of Colonies.....	318
10.3 How Bees Are Exposed to Pesticidal Hazards.....	318
10.3.1 Cotton.....	318
10.3.2 Brassica and Vegetable Seed-Crops.....	319
10.3.3 Sunflower.....	319
10.3.4 Sesame.....	319
10.3.5 Seed Crops.....	320
10.3.6 Pulses.....	320
10.3.7 Cucurbits.....	320
10.3.8 Tobacco.....	320
10.3.9 Pome and Stone Fruits.....	320
10.3.10 Other Fruit Crops.....	321
10.4 Phytotoxicity to Plants.....	321
10.5 Intensity of Damage to Bees by Pesticides.....	321
10.5.1 Indirect Effects of Pesticides on Bees.....	322
10.6 Pesticides Involved – Basic Types and Classes.....	322
10.6.1 Classes of Pesticides.....	322
10.7 Sex Lures, Attractants, and Other Hormones.....	326
10.8 Biological Control Agents (Parasitic and Predatory Insects).....	326
10.9 Nonchemical Control.....	327
10.10 Toxicity of a Pesticide.....	327
10.11 How Bee Poisoning Occurs.....	327
10.12 Symptoms of Bee Poisoning.....	328
10.13 Groups of Insecticides Based on Their Toxicity to Bees.....	330
10.13.1 More Toxic Insecticides.....	330
10.13.2 Less Toxic Insecticides.....	330
10.13.3 Non-toxic Insecticides.....	330
10.13.4 Relative Toxicity of Pesticides.....	330
10.13.5 Poisoning and Developmental Stages.....	331
10.13.6 Development of Adult.....	331
10.13.7 House Bees.....	331
10.13.8 Field Bees.....	331

10.14	Factors Influencing the Toxicity of Insecticides to Bees.....	337
10.14.1	Temperature	337
10.14.2	Age and Size of the Bees	338
10.15	Protection of Bees	338
10.15.1	How Bees Can be Protected from Pesticide Poisoning.....	338
10.15.2	Read the Pesticide Label Carefully	338
10.15.3	Use Less Toxic Compounds	338
10.15.4	Types of Formulation and Their Toxicity to Bees	338
10.15.5	Use Less Toxic Formulations	339
10.15.6	Dust Formulations	339
10.15.7	W.P./W.D.P. Formulations	339
10.15.8	Microencapsulated Pesticides.....	339
10.15.9	The Mode of Pesticide Application.....	339
10.15.10	Do Not Treat Crops in Bloom	340
10.15.11	Minimize Spray Drift	340
10.15.12	Use Pesticides Only When Needed	340
10.15.13	Apply Pesticide When Bees Are Not Flying.....	340
10.15.14	Do Not Contaminate Water	340
10.15.15	Identify Attractive Blooms	341
10.15.16	Notify Beekeepers	341
10.15.17	Disposing of Unused Pesticides	341
10.15.18	Use Integrated Pest Management (IPM) to Reduce Pesticide Hazard.....	341
10.15.19	Use of Repellents.....	341
10.15.20	Disposing of Unused Pesticides	342
10.15.21	Inform Presence of Apiary	342
10.15.22	Notify Beekeepers and Inform Presence of Apiary	342
10.16	Management of Poisoned Colonies.....	343
10.16.1	Managing Pesticide Drift.....	343
10.16.2	Distance Water Droplets Drift While Falling 10 ft in Winds of 3 Miles Per Hour.....	344
10.16.3	Application Pressures	344
10.16.4	Nozzle Construction	345
10.16.5	“Thickening” or “Drift Control” Adjuvants	345
10.16.6	The Weather Conditions	345
10.16.7	Pesticides Should Never be Applied During High Wind Conditions (Greater than 10 mph)	345
10.16.8	Temperature and Humidity.....	346
10.16.9	Height and Orientation of Sprayer Nozzles.....	346

10.16.10	Avoiding Pollution of Ground and Surface Waters.....	346
10.16.11	Irrigate in a Manner that Reduces Pesticide Movement	346
10.17	Honey Bee Indemnity Program.....	347
10.18	Plant Poisoning.....	347
10.19	Purple Brood	347
10.20	Paralysis	347
10.21	Milkweed Pollinia	349
	References	349
11	Pollination in Cages	353
11.1	Introduction	353
11.1.1	Buzz Pollination	353
11.2	Impact of Greenhouse Conditions on Bee Behaviour.....	354
11.3	Influence of Floral Biology of Greenhouse Plants on Pollinators.....	355
11.4	Impact of Physical Properties of Greenhouse on Pollination	356
11.5	Enrichment of Atmosphere with Carbon Dioxide	357
11.6	Greenhouse Temperature and Humidity	357
11.7	Greenhouse Pollination	359
11.7.1	Caging Effect.....	359
11.7.2	Construction Material for Enclosures.....	359
11.8	Type of Bees for Caging.....	359
11.9	Size of the Colony	359
11.10	Sustaining the Caged Conditions	360
11.11	Contamination of Seed Crops	360
11.12	Site of Colony Location	360
11.13	Bee Activity and Loss	360
11.14	Bee Vision	361
11.15	Categories of Insects for Greenhouse Pollination	364
11.15.1	Bumblebees	364
11.15.2	Honeybees	365
11.15.3	Solitary Bees.....	371
11.15.4	Blowflies	374
11.15.5	Stingless Bees	378
11.16	Pollination of Tomato.....	384
11.17	Pollination Levels.....	386
11.18	Conclusions and Future Strategies	387
	References	387
12	Pollination for Hybrid Seed Production	397
12.1	Introduction	397
12.2	Heterostyly	398

12.3	Pollination Problems in Different Crops	398
12.3.1	Onion (<i>Allium Cepa L.</i>).....	398
12.3.2	Safflower (<i>Carthamus tinctorius L.</i>)	399
12.3.3	Sunflower (<i>Helianthus annus L.</i>)	399
12.3.4	Brussels Sprout, Cabbage, Cauliflower (<i>Brassica oleracea L.</i>)	400
12.3.5	Cotton (<i>Gossypium</i> species).....	401
12.3.6	Soybean (<i>Glycine max (L.) Mess.</i>).....	402
12.3.7	Broad or Field Bean (<i>Vicia faba L.</i>)	402
12.3.8	Carrot (<i>Daucus carota L.</i>).....	403
12.3.9	Cucumber (<i>Cucumis saliva L.</i>)	403
12.3.10	Tomato (<i>Lycopersicon e.sculenius Mill.</i>)	404
12.3.11	Buckwheat (<i>Fagopyrum esculentum Moench</i>)	404
12.3.12	Rape Seed-Mustard (<i>Brassica spp.</i>)	404
12.4	Pollination in Green Houses/Cages.....	405
12.5	Type of Material Used for Constructing Green Houses/Cages	406
12.6	Size of Colonies and Their Management	406
12.7	Use of Honeybees for Pollination of Some Important Crops in Greenhouses/Cages	407
12.7.1	Strawberries (<i>Fragaria</i> spp.)	407
12.7.2	Onion (<i>Allium cepa L.</i>)	407
12.7.3	Runner Bean (<i>Phaseolus coccineus L.</i>)	407
12.7.4	Tomatoes (<i>Lycopersicon esculentum Mill.</i>).....	408
	References	408
13	Biochemical Basis of Plant-Pollination Interaction	413
13.1	Introduction	413
13.2	Role of Flower Colour.....	415
13.2.1	Colour Preferences of Pollinators	416
13.2.2	Chemical Basis of Flower Colour.....	417
13.3	Evolution of Flower Colour	421
13.4	Honey Guides	425
13.5	Role of Flower Scent	427
13.5.1	Types of Scent.....	427
13.5.2	Insect Pheromones and Flower Scents.....	434
13.5.3	Odoriferous Chemical Compounds in Plants	437
13.5.4	The Role of Thermogenecity in the Release of Odors	439
13.6	Timing of Inflorescence and Pollination	440
13.7	Evolutionary Significance and Ecological Functions of Thermogenecity and Chemoattractants.....	441
13.8	Role of Nectar and Pollen	443
13.8.1	Sugars of Nectar	443
13.8.2	Nectar and Pollen Constituents.....	444
13.8.3	Amino Acids of Nectar	446

- 13.9 Lipids in Nectar 449
 - 13.9.1 Nectar Toxins 449
 - 13.9.2 Extrafloral Nectaries 450
 - 13.9.3 Nutritive Value of Pollen 451
- 13.10 Conclusions 452
- References 453
- 14 Pollination Energetics** 459
 - 14.1 Introduction 459
 - 14.2 Energy Requirement-Reward System and Pollinator-Plant Interaction 460
 - 14.2.1 Energy Intake 460
 - 14.2.2 Energy Reward and the Competition for Food 461
 - 14.2.3 Nectar Sugar Concentration Fluctuations 462
 - 14.2.4 Feeding Niches of Pollinators in Relation to Their Preferred Nectar Concentration Ranges 463
 - 14.2.5 Nectar Secretion Pattern and Its Influence on Pollinator-Plant Interaction..... 463
 - 14.2.6 Nectar Composition and Caloric Content – Their Influence on Pollinator-Plant Interaction 464
 - 14.2.7 Floral Visits in Relation to Quality of Food 466
 - 14.3 Measurement of Energy Costs 466
 - 14.4 Energy Expenditure 467
 - 14.5 Cost-Benefit Analysis and Pollinator Behaviour 469
 - 14.6 Conclusion..... 472
 - References 472
- 15 Climate Change and Pollinators**..... 479
 - 15.1 Introduction 479
 - 15.2 Pollinators an Essential Component for Ecosystem Functioning 481
 - 15.2.1 The Pollinators 481
 - 15.2.2 Diversity of Pollinators 482
 - 15.2.3 Pollination and Ecosystem Functions 483
 - 15.2.4 Contribution of Pollination to Food Security 483
 - 15.2.5 Decline of Pollinators 484
 - 15.2.6 The Impact of Declining Pollinator Populations on Agriculture 486
 - 15.2.7 Consequences of Decline..... 487
 - 15.2.8 Endangered Mutualisms: The Conservation of Plant-Pollinator Interactions..... 488
 - 15.2.9 Causes of Decline 489
 - 15.3 Climate Change and Pollinators 491
 - 15.3.1 The Consequences of Pollinator Population Declines 491
 - 15.3.2 Climate Change and Butterfly Species Richness..... 491

- 15.3.3 Climate Change Threatens Pollination
 - Timing of Flowering..... 493
- 15.3.4 Phenology and Climate Change..... 494
- 15.3.5 Geographic Responses to Climate Change..... 495
- 15.3.6 Temporal Responses to Climate Change 495
- 15.3.7 Changes in Species Interactions 498
- 15.3.8 Bees and Flowers Are Disappearing Together..... 499
- 15.4 Impact of Climatic Change on Pollinators and Agriculture..... 500
- 15.5 Pollination as a Tool in Adaptation to Changing
 - Environments and Minimising Risk 500
- 15.6 Global Warming May be Partly to Blame
 - for Honeybee Deaths..... 501
- 15.7 How to Overcome Climate
 - Change for Better Pollination..... 501
- 15.8 Sustainable Agriculture Mitigates Climate
 - Change and Has Climate Adaptation Potential..... 501
- 15.9 Plant Reproductive Biology Studies Crucial
 - for Conservation..... 502
- 15.10 Conclusions 502
- References 503
- 16 Pollinators as Bioindicators of Ecosystem Functioning..... 509**
 - 16.1 Introduction 509
 - 16.2 Inhibiting Factors in Pollinator Build Up..... 514
 - 16.2.1 Pesticides 514
 - 16.2.2 Pollution 515
 - 16.3 Ecosystemic Stress and Health..... 517
 - 16.3.1 Butterflies 518
 - 16.3.2 Honeybees as Bio-Indicators 518
 - 16.4 Monitoring of Pesticides 519
 - 16.4.1 Monitoring of Radionuclide 521
 - 16.4.2 Birds as Bioindicators..... 526
 - 16.4.3 Bats as Bioindicators 527
 - 16.4.4 Euglossine as Biological Indicators..... 530
 - 16.5 Conclusions 531
 - References 532
- 17 Decline in Pollinators..... 545**
 - 17.1 Introduction 545
 - 17.2 The Pollinators 546
 - 17.2.1 Pollinators and Ecosystem Functioning 546
 - 17.2.2 Pollinator Decline: Importance..... 547
 - 17.3 Historical Perspectives 549
 - 17.3.1 Do Pollination Deficits Exist in Agroecosystems?..... 549
 - 17.3.2 Status of Pollinators Decline 553

- 17.3.3 Declining Biodiversity..... 553
- 17.3.4 Ecological and Economic Consequences
of Pollinator Declines 556
- 17.4 Honey Bee Colony Losses..... 558
 - 17.4.1 The Decline of European Honeybees 558
- 17.5 Reasons for Pollinator Decline..... 563
 - 17.5.1 Habitat Fragmentation 564
 - 17.5.2 Habitat Alteration 565
 - 17.5.3 Habitat Loss..... 565
 - 17.5.4 Habitat Changes..... 566
 - 17.5.5 Introduction of Alien Species:
Plants, Pollinators, Pests and Pathogens 567
 - 17.5.6 Major Threat from *Apis mellifera* 568
 - 17.5.7 Pesticide Poisoning of Honeybees..... 569
 - 17.5.8 Diseases and Enemies..... 570
 - 17.5.9 Human Predations 572
 - 17.5.10 Global Warming and Climate Change..... 572
 - 17.5.11 Population Vulnerability Analysis (PVA)..... 573
 - 17.5.12 Other Factors 574
 - 17.5.13 Consequences of Decline 574
 - 17.5.14 Colony Collapse Disorder (CCD)..... 575
 - 17.5.15 Agriculture Practices 576
- 17.6 The Decline of Other Bee Species 577
 - 17.6.1 Multiple Drivers and Pressures..... 578
 - 17.6.2 The Pollination Crisis 578
 - 17.6.3 Impacts of Pollinator Declines 579
 - 17.6.4 The Impact of Declining Pollinator
Populations on Agriculture 580
 - 17.6.5 Threats to Pollination Systems 581
- 17.7 International Conventions/Relevant Policy
Measures/Recommendations..... 583
 - 17.7.1 What Should be Done Now? 583
 - 17.7.2 Level of Knowledge/Awareness 586
 - 17.7.3 National Policy on Pollinators 586
 - 17.7.4 Conservation and Utilization of Pollinators 586
 - 17.7.5 The International Response 588
- 17.8 Conclusions 589
- References 590
- 18 The Problem of Diseases in Bees..... 603**
 - 18.1 Introduction 603
 - 18.2 Problem of Diseases in Honeybees 605
 - 18.2.1 Bee Diseases and Parasites 606
 - 18.3 Diseases and Parasites: Changes in Disease
Profiles and Incidence 608

18.4 How Will the Pathogen/Bee Interaction Evolve? 609

18.5 Consequences for Bee Health and Socioeconomic Impact 609

18.6 Climate Change Can Facilitate
the Emergence of New Invasive Species 610

18.7 Recent Cases of Mortality 610

18.8 Pollinators and Biodiversity 610

18.9 Threats to Wild Pollinators 611

 18.9.1 Diseases and Enemies of Wild Pollinators 612

18.10 Chalkbrood Control in Alfalfa Leafcutting Bee 616

 18.10.1 Life Cycle 617

 18.10.2 Symptoms 618

 18.10.3 Prevention and Control of Chalkbrood Disease 618

18.11 The Alkali Bee 623

18.12 Problems in the Management of Bee Diseases 623

 18.12.1 Resistance to Acaricides 624

 18.12.2 Fluvalinate Resistance 624

 18.12.3 Coumaphos 625

 18.12.4 Amitraz Resistance 625

 18.12.5 Resistance Management 625

 18.12.6 AFB 626

 18.12.7 Alternative Treatments Strategies 626

18.13 Management of Diseases 626

 18.13.1 Breeding Queens for Disease Resistance 626

18.14 Conclusions 628

References 628

19 Consequences of Introduced Honeybees

Upon Native Bee Communities 635

19.1 Introduction 636

19.2 Distribution and Abundance of Introduced Bees 637

19.3 Competitions with Native Organisms for Floral Resources 640

19.4 Effects on Foraging Behavior 640

19.5 Evidence for Population-Level Changes 643

19.6 Competition for Nest Sites 645

19.7 Transmission of Parasites or Pathogens
to Native Organisms 645

19.8 Effects on Pollination of Native Flora 646

19.9 Pollination of Exotic Weeds 648

19.10 Loss of Genetic Diversity: Causes and Consequences 650

19.11 Causes and Consequences of Declining
Apis cerana Diversity 651

 19.11.1 Major Threat from *Apis mellifera* 651

 19.11.2 Exotic Pollinators 652

19.12 Impact of Importations on Native Bees 654

 19.12.1 Import of Pollinators 654

19.12.2	Import of Honeybee Packages, Queen Bees and Spread of Enemies and Diseases	654
19.12.3	Africanized/Killer Bees	655
19.12.4	Cape Bee Problem	656
19.13	Conclusions	657
	References	658
20	Genetically Modified Plants and Bees	669
20.1	Introduction	669
20.2	GM Material in Plant Parts Collected by Bees	671
20.2.1	Pollen	671
20.2.2	Nectar	673
20.2.3	Plant Resins and Gums	674
20.2.4	Plant Sap and Honeydew	674
20.3	Records of GM Material in Bee Products	675
20.3.1	GM Plants Occurring in Hive Products	677
20.4	Is GM Honey Safe?	678
20.5	Bees and Gene Pollution	679
20.6	Impact on Beekeepers	679
20.6.1	Impact on Wild Bees	680
20.7	Bt Insect Protection of Crops and Honey Bees	680
20.8	Safety Assessment of Bt Crops	681
20.8.1	Honeybee Larva	681
20.8.2	Adult Honeybee	682
20.9	Potential Impacts of GM Plants on Bee Health	683
20.10	Direct Effects of Novel Proteins on Bees	683
20.11	Indirect Effects of GM Plants on Bees	685
20.12	Bumblebees and Purified Bt Protein	685
20.13	Honeybees and Bt Maize	686
20.14	Honeybees and Herbicide Tolerant Oilseed Rape	686
20.15	Honeybees and Other Transgenic Plants	687
20.16	Transgenic Plants and Honeybee Colony Collapse Disorder CCD	687
20.17	Gene Transfer in the Honeybee Gut	688
20.18	Bee Foraging Distances	690
20.19	Accidental Inclusion of Wind-Borne Pollen in Bee Products	691
20.20	Feasibility of the Crop/Bee Separation Approach	691
20.21	Screening the Crop to Exclude Bees	691
20.22	Bee Management Techniques	
	to Direct Bees to Visit Particular Crops	692
20.22.1	Bee Attractants and Other Methods to Maximise Foraging on a Crop	692
20.22.2	Bee Repellents and Other Methods to Prevent Bee Visits to a Crop	693

20.23	Biotechnological Solutions	694
20.23.1	Modification of Chloroplast DNA	694
20.23.2	GM Plants Without Pollen	695
20.23.3	GM Plants Without Flowers.....	695
20.23.4	Post-harvest Honey Treatments	696
20.24	Market Reaction to Honey from Countries Where GM Crops Are Grown.....	696
20.24.1	Market Reaction to Honey from Canada	697
20.24.2	Market Reaction to Honey from Argentina, the United States and Australia.....	697
20.25	Potential Impacts of GM Plants on Bee Health	698
20.26	GMO Crops and Malnutrition of Bees.....	698
20.26.1	Direct Effects of Novel Proteins on Bees	699
20.26.2	Indirect Effects of GM Plants on Bees.....	699
20.26.3	Contamination of Crops.....	700
20.27	Conclusions.....	700
	References.....	701
21	Management of Pollinators for Crop Plants and Wildlife.....	709
21.1	Introduction.....	709
21.2	Conservation Measures	711
21.2.1	Assessment of Pollinators and Pollination Services	711
21.3	Capacity Building in Conservation and Management of Pollination Services	715
21.3.1	Formal Education.....	715
21.3.2	Informal Education Short Courses.....	716
21.3.3	Farmer and Extension Training.....	716
21.4	Mainstreaming Conservation and Management of Pollination Services.....	717
21.4.1	Intergovernmental Initiatives	717
21.4.2	Government Policy.....	718
21.4.3	Protected Areas	719
21.4.4	Biodiversity Regulations	719
21.4.5	Red Lists	720
21.4.6	National Pollinator Initiatives	720
21.4.7	Agriculture	720
21.5	Targeted Research Programmes.....	729
21.5.1	Apple Pollination in India.....	729
21.5.2	Managing Indigenous Pollinators	730
21.5.3	Passion Fruit in Brazil.....	730
21.5.4	Alfalfa Fields in North America	730
21.5.5	Reducing Pesticide Use in Canada	731
21.5.6	Promoting Pollinator Husbandry	731
21.5.7	Indigenous Honey Bees in Asia.....	731

21.5.8	Honey Bees in Australia	731
21.5.9	Native Bees in Australia	732
21.5.10	Eastern Honey Bee for Pollination	732
21.5.11	Conservation Measures	732
21.5.12	Rehabilitation of Landscapes	732
21.6	Targeted Research Programmes	733
21.7	Promoting Pollinator Husbandry	733
References	733
22	The Role of Pollination in Improving Food Security and Livelihoods	737
22.1	Introduction	737
22.2	The Pollinators	738
22.3	The Issues: The Impact of Declining Pollinator Populations on Agriculture.....	739
22.3.1	Case Study: Cash Crops Farming in the Himalayan Region.....	740
22.4	The Role of Pollination in Improving Food Security and Livelihoods	742
22.5	Inadequate Pollination as a Factor Affecting Crop Productivity.....	743
22.6	Pollinator Diversity and Its Role in Enhancing Crop Productivity.....	744
22.7	The Issue of Declining Pollinator Populations	744
22.7.1	Impact of Decline in Pollinator Population and Diversity	745
22.8	The Importance of Pollinator Management for Cash Crop Pollination in the Himalayas.....	746
22.9	Managed Pollination as a Solution to Address the Immediate Problem of Cash Crop Pollination.....	747
22.10	Honeybees as the Most Efficient and Manageable Pollinators	747
22.10.1	Experimental Research on the Impact of Honeybee Pollination on Crop Productivity in the Himalayan Region	748
22.10.2	The Significance of Honeybee Diversity for Pollination	750
22.10.3	Managed Pollination Through Using Honeybees for Apple Pollination in the Himalayan Region: A Case Study from Himachal Pradesh, India	750
22.11	Hand-Pollination (Using Humans as Pollinators): A Case Study from Maoxian Valley, China.....	751
22.12	Challenges in Managed Crop Pollination	752
22.13	Awareness Raising	753
22.14	Including Pollination as a Technological Input to Agricultural Development Packages	754

22.15	Influencing Thinking About Bees and Beekeeping	754
22.16	Strengthening Research and Development Institutions	754
22.17	Human Resources Development and Capacity Building	755
22.18	Crop Pollination Investment Prospects	755
22.19	Gender Concerns in Pollinator Management and Managed Pollination.....	755
22.20	Beekeeping Helps to Create Sustainable Livelihood	757
	22.20.1 Beekeeping Assets	757
	22.20.2 Natural Capital Assets.....	757
22.21	Beekeeping and Ancillary Industries in Improving Food Security and Livelihoods	760
	22.21.1 Industries Necessary for Apiculture.....	761
	22.21.2 Industries Dependent on Apiculture	762
22.22	Conclusions	767
	References.....	767
23	Capacity Building and Awareness for Pollinators	771
23.1	Introduction.....	771
23.2	Pollinator and Pollination Awareness	772
23.3	Capacity Building in Conservation and Management of Pollination Services.....	773
	23.3.1 Following Strategy for Capacity Building Implementation is Proposed	774
23.4	Mainstreaming	777
	23.4.1 Activities	777
	23.4.2 Ways and Means	778
	23.4.3 Timing of Expected Outputs	778
23.5	Capacity Building Has Been Successful in Exploiting Pollinators as Illustrated in Following Few Examples	779
	23.5.1 Agave and Tequila.....	779
	23.5.2 The Forgotten Pollinators Campaign and Book.....	781
	23.5.3 Education and Training.....	781
	23.5.4 Training in Pollinator Identification.....	782
	23.5.5 Parataxonomists in Costa Rica.....	783
	23.5.6 Overcoming the Taxonomic Impediment in Mexico.....	783
	23.5.7 Sharing Information in Africa.....	784
	23.5.8 Using Communication Technology in Brazil	784
23.6	Conclusions.....	784
	References.....	785
	Index.....	787