Crops, Browse and Pollinators in Africa: An Initial Stock-taking

Crops, Browse and Pollinators in Africa

An Initial Stock-taking

produced by the
African Pollinators Initiative

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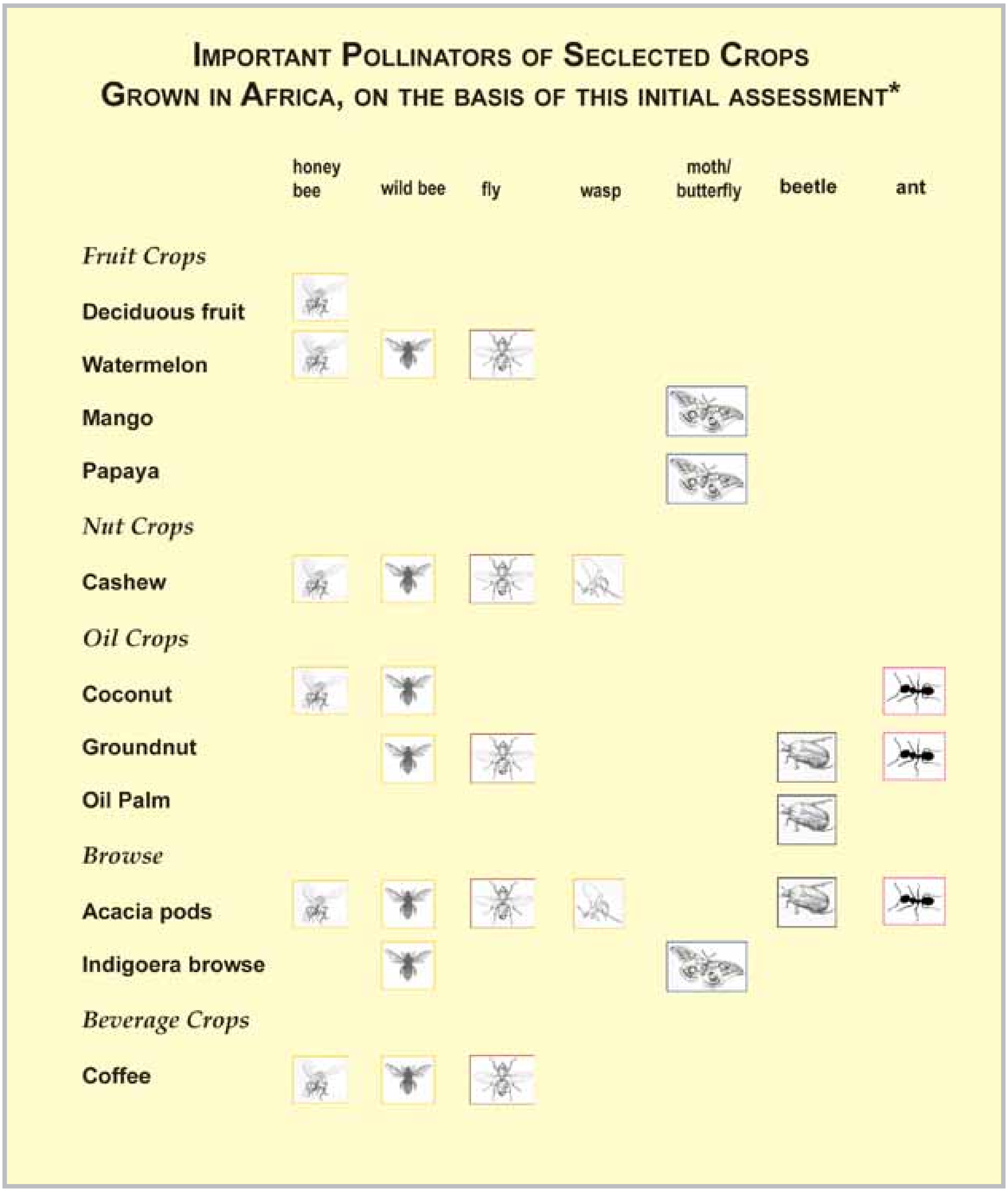
Frontpiece:



** note that in none of the systems studied did vertebrate pollinators play a documented role.*

Preface

When the Fifth Conference of the Parties to the Convention Biological Diversity established an International Initiative for the Conservation and Sustainable Use of Pollinators (also known as the International Pollinators Initiative-IPI) in 2000 (COP decision V/5, section II), FAO was requested to facilitate and co-ordinate the Initiative in close co-operation with other relevant organisations. A Plan of Action for the IPI was adopted at COP 6 (decision VI/5), providing an overall structure to the initiative, with four elements of assessment, adaptive management, capacity building and mainstreaming.

FAO, through the FAO/Netherlands Partnership Programme, supported the initial establishment of a regional African Pollinator Initiative, the development and publication of its Plan of Action in 2003, and an initial stocktaking of pollinator-dependent crops and browse plants in Africa. The stocktaking document has only been available in electronic form; support from the Government of Norway has permitted its publication in 2007.

We hope that the information contained in this stocktaking document will inspire others to make assessments of pollination services in their countries or regions as appropriate. We would encourage those that do so to share these with FAO for wider dissemination, through the following address: pollination@fao.org.

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Summary of Lessons Learned

Lessons learned . . .
in South African pollination assessments

Honeybees were essential as pollinators of the five orchard crops; some exotic weed species were beneficial to indigenous pollinators especially honeybees in supplying nectar and pollen; but the greatest variety and numbers of pollinator species were present on indigenous flowering plants.

Lessons learned . . .
in Ghanian pollination assessments

In Ghana, farmers would appreciate more extension information on pollination services.

In a rapid assessment of crop pollination, it was found that even though honeybees visit mangos early in the morning, the main pollinators of mango seem to be various fly species, which remain on the little flowers most of the day. Cashew had wider species diversity of pollinators, while for oil palm beetles are the main pollinators. The main pollinator of Coconut are stingless bees, some wasps and other small bees. Flower visitors to groundut were noted, including halictid bees

Lessons learned . . .
in Kenyan pollination assessments

In Kenya, it was found that farmers' knowledge of pollination is limited: many farmers lump pollinators together with insect pests, and do not explicitly manage to conserve them, although pollinators may contribute substantially to yields at no cost to the farmer. Most researchers working on projects related to pollination are addresssing bee-keeping, or bee taxonomy. Other aspects of pollination services are not being addressed.

In a rapid assessment of crop pollination needs, it was noted that while bees that nest in cavities are often considered the most manageable, non-honeybee pollinators of watermelon made use of on-farm conditions to nest in the field soil. Conditions promoting them to nest could be studied and utilised to increase watermelon pollination. Papaya needs pollinators able to fly long distances between scattered trees with separate male and female blossoms. Recommendations for conserving the hawkmoths that pollinate papaya effectively are needed. Although avocado is an exotic tropical fruit to Kenya, its reproduction has adapted well to a diverse range of local pollinators. Coffee producers do not seem to be aware that pollination can increase yields, and are removing habitat on farm for wild bee populations.

Browse pollinators are important, but often overlooked. Most of the important Acacia pollinators nest in dead wood, making room for low-tech pollination management in that farmers that depend on this resource should not denude the areas of dead wood. Many crop and browse pollinator species could only be identified to genera. This severely limits our ability to assess whether they are shared amongst several crops, or specific to individual crops.

Introduction

Pollination is an ecosystem service that is key to food security. Pollinators are essential for many fruit and vegetable crops. In agriculture, especially amongst pollen-limited crops, promoting pollination services is a means of increasing productivity without resorting to expensive agricultural inputs of pesticides or herbicides. Indeed, pollination services are most likely underpinning productivity in many crops without farmers even recognising it, so long as habitat and alternative pollinator forage are readily available as they often are in smallholder farming systems.

By developing larger and larger fields and landscapes for agriculture, we remove the habitat that pollinators may need. Increasing dependence on pesticides for pest control is also highly detrimental to beneficial insects such as pollinators, unless planned and undertken with extreme care. Pollination is a service nature provides that we have tended to take for granted, and that we often do little to encourage until we start to lose it. As wild ecosystems are increasingly converted to more human-dominated uses to meet the compelling demands of food security, it is critical for us to understand what pollination services are most important for food security, and how we can preserve pollinator services in sustainable farming systems.

A crop's pollinator dependence differs between species, including between crops and crop varieties. Some plants must be cross-pollinated, others do not need pollinators but produce better fruit and seed if pollinated, and a number are strictly self-pollinated. Further, plants differ in their pollinator-type requirements; some require specific pollinators while others are pollinated by a variety of visitors, and many are wind pollinated. Effective pollinators of the same crop may vary from one site to another. Specific knowledge on pollinator dependence and types is important for agriculture and biodiversity (including agro-biodiversity) conservation. With this objective, researchers in Ghana, Kenya and South Africa were supported by the United Nations Food and Agriculture Organisation in 2003 to undertake an initial assessment of pollination needs and gaps in knowledge of the key pollinators of a few crops, and indigenous plants used by people or livestock (*Acacia* and *Indigofera*), in their respective countries. This assessment included both literature reviews and field observation; and is on-going. The long-term aim of assessments is to identify the key pollinators and prioritize vulnerable pollination systems, in particular those in which explicit pollinator management practices can have the most beneficial impacts. As the African Pollinator Initiative plan of action has specified, methodologies were used that must give results that are scientifically justifiable, and comparable.

Identifying the State of Knowledge: Farmer's Knowledge in Kenya

Rachel Kagoiya

Farmers around the world understand better than most of the public that good environmental health is fundamental to their sustainable existence, but often in a holistic way that may not include an in-depth understanding of the role of pollination. The importance of ecosystem services will not be 'mainstreamed' or become considered as a part of accepted farming practice unless the farming community understands explicitly what it is and how it works. A good example of this is pollination services. Globally, within the United Nations Convention on Biological Diversity, and regionally, within the African Pollinator Initiative, the contribution of pollinators for increasing genetic diversity, adaptation, seed set or crop production and crop quality, and natural regeneration of wild species has been recognised, and the need to conserve pollinators has been stressed. Yet the public's, including farmers', knowledge of the role of pollinators, remains poor. Surveys carried out amongst farmers in central Kenya highlighted the fact that many farmers lump pollinators together with insect pests, and do not explicitly manage to conserve them, although pollinators may substantially contribute to yields at no direct cost to the farmer. Ecosystem services such as pollination and soil biodiversity are aspects of the environment that relate closely to human livelihoods, and may convince the public that biodiversity is not only wild animals that may damage their crops, but also creatures that live on their farms and help to sustain crop production. Further public awareness programmes on ecosystem services are merited.

Farmers' and Agricultural Extension Agents' Knowledge in Ghana

Peter Kwapong

In Ghana, interviews with farmers, extension agents, and agricultural lecturers indicated that all of these groups are aware of pollination and pollinators, to varying degrees. All respondents agreed that pollination is important in agriculture and that absence of pollination will not result in fruit and seed formation. Only a few believed that plants can reproduce vegetatively. Respondents (83%) think that crop yield increases when flowers are sufficiently pollinated. But most people sampled (93%) think that humans have a major role to play in ensuring adequate pollination and only a few understood that it is a natural ecosystem service that should be allowed to go on unaided.

Farmers had limited knowledge on pollination and pollinators. With respect to pollinators, most of the farmers said they left any insect found on plants during flowering not because they really understand their role but they think bees provide honey for medicinal purposes and also form part of God's creation and must be left alone. A few farmers however claim that they sprayed bees found on their crops for fear of attack. In order to promote pollination services some of the respondents suggested natural habitat should not be destroyed through bush burning, deforestation and insecticide spraying. Some people think that pollinator friendly type of farming should be adopted to protect pollinators from physical, chemical and biological enemies.

Extension agents had more knowledge on pollination: for example, 75% of Agricultural agents thought that pollinators need to be protected from sprays compared to 31% of farmers who think the same.

But such information was not being disseminated: farmers felt that the Ministry of Agriculture had not been proactive in promoting the awareness and occurence of pollination and the need to protect the service. In terms of help to farmers, 49% of the agents think that they have created the pollinator awareness to farmers. From the farmers' point of view, 73.7% said the have had no help from the Ministry of Agriculture on the subject whilst 26.3 said they have received such help (awarenesss). The agents (75%) think that the Ministry has no policy to promote the awareness of pollination and pollinators in crop production.

Civil Society and Research Organisations: Knowledge of Pollination

Dino Martins

A survey of a biodiversity conservationists and practitioners, researchers and non-governmental organisations (NGOs) in Kenya was carried out to assess the level of knowledge of pollination services. Questionnaires were sent to all members of the African Pollinator Initiative. Most respondents were scientists, or technicians working for scientific institutions, and to a lesser extent, from conservation civil society organisations.

Organisations involved in conservation programmes carried out their work through community projects, public education and awareness and ecosystem management initiatives. Only two respondents identified with species-focused programmes. This highlights an important trend towards a community and public awareness focus in terms of the conservation message, and an overwhelming endorsement of the ecosystem approach to management practice. This is important information for the planning of pollination-related activities and projects.

Most of the respondents working in science and conservation have a basic knowledge of pollination as the process that transfers pollen and results in fertilization. People were also aware that pollination requires an agent, but only two respondents identified these in this question as including insects. While basic knowledge of what pollination is, as a process, is widespread, fewer people are aware that many different organisms, and insects in particular, are important pollinators. Most organisations and individuals indicated that pollination or pollinators were included in some form or aspect of their progammes. But the means of addressing pollination was limited to: bee keeping or taxonomy. For example, one organisation encourages farmers to grow flower-rich crops, including sunflower and fodder trees to boost honey production. Education was seen as the main means to incorporate knowledge on pollination and pollinators into agriculture and biodiversity conservation projects. No organistion promoted any direct conservation needs and/or practices directly related to pollinators. This is one area where much work can be done by API, in raising real awareness among conservation and biodiversity-related practitioners.

Respondents identified the two most important training needs as bee/pollinator conservation (38%) and pollination ecology/assessment (38%). Seventy percent of respondents felt that their knowledge of pollination was only average, and 10% felt it was low. There is clear awareness of the need for targeted education and awareness-raising among key groups- a need that API should seek to fill.

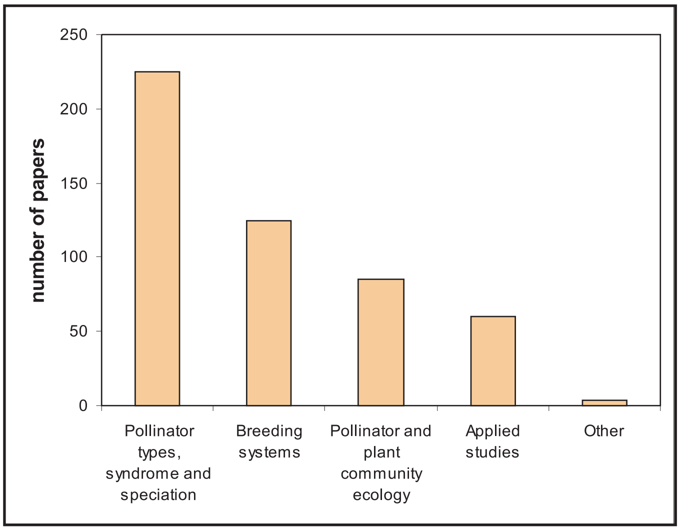
The above responses highlight the need for a lot of groundwork on pollinator awareness among natural biodiversity practitioners and conservationists. Knowledge on the diversity of pollinators and range of pollination systems needs to be improved. API has a real role to play in this, through the dissemination of existing studies and building links with institutions that can go on to develop further pollination-related programmes.

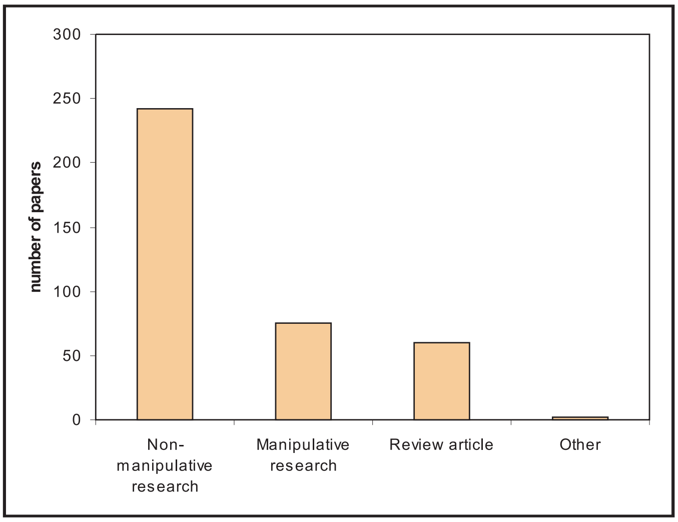
Identifying the State of Knowledge In the Literature

Barbara Gemmill-Herren

The literature covering pollination ecology in Africa is not new: articles were published as long ago as 1890 in South Africa, on the pollination of bananas, strelizias and Traveler's palm. (Scott-Elliot 1890) But it is, compared to other continents, fairly sparse and not with an applied aspect. As part of a joint publication of the African Pollinator Initiative, a comprehensive literature review was carried out, compiling all known literature references to pollination studies in Africa (Rodger, Balkwill and Gemmill 2004). The review was published in a special issue of the International Journal of Tropical Insect Science, dedicated to the African Pollinator Initiative. The bibliography is intended for widespread use by those practitioners and research organizations contemplating pollination research in Africa. It will be continually updated and maintained as a searchable database on the API website, currently hosted by PPRI in South Africa at (http://www.arc.agric.za/home.asp?pid=3493)

The review found that of 355 articles (now up to 400, with further searches and publications) focused on different aspects of pollination in Africa, the vast majority have focused on the evolutionary aspects of pollination syndromes and breeding systems (Figure 1). Less than one-fifth (72) addressed pollination in agricultural systems, or with specific crops. Research in Africa has identified interesting mutualisms, such as that between figs and fig wasps and bats and various trees (Baijnath et al., 1983, Compton 1990, Galil and Esikovitch 1960). Yet applied, agricultural aspects of pollination have received much less attention, and many of these studies remain in the"grey literature", not easily traceable or accessible to practitioners in the field.





FIGURES 1 AND 2.

Out of all the papers identified, only 93 included manipulative (experimental) work (Fig. 2). Pollination biology is a field that lends itself readily to short-term, reasonably inexpensive manipulation experiments that can put observations and hypotheses to a test. There is scope for considerably more hypothesis testing and deductive science than has been conducted on the continent in pollination studies up until now.

Given the paucity of specific information linking pollination services with crop production in Africa, people wanting to know about pollination needs in Africa will turn to the standard reference volumes on pollination first. To assist with this, and to identify the prominent gaps in knowledge with respect to African crops, the literature review also included the development of a table featuring the important commercial commodities within Africa known to benefit from animal vectors for pollination, and where information on these can be found in these reference volumes this is indicated. As it is increasingly recognised that pollination ecology is highly site-specific, and local, native pollinators should be promoted over exotic solutions, we have added an additional column noting if and how many pollination studies for a particular commodity have been carried out in Africa (Table 1). This may help us to priortise future studies, to fill in the obvious gaps.

Table 1. Commodity	Free 1996	Crane & *pages* 1984 *pages*	McGregor 1976 Walker	Known Pollinator(s) from literature	Studies conducted within Africa
Grain legumes					
Bambara groundnut, *Voandzeia subterranea*	342-3	73	-	Self pollinated and self fertile ants noted pollinating in Ghana	2
Broad beans, *Vicia faba* var. *major*	298	23	/chap4/broad.html	Self and bees	1
Common (field) bean, *Vicia faba* var. *minor*	298	23	/chap4/broad.html	Self and bees	1
Cowpea, *Vigna unguiculata*	341-2	107	/chap4/cow.html	Self and bees	2
Lima bean, *Phaseolus lunatus*	269-70	22	/chap4/lima.html	Self and bees	0
Pigeon pea, *Cajanus cajanus*	317-20	107	/chap4/pig.html	Probably self and bees but not well known	2
Vegetables					
Amaranth, *Amaranthus* spp.	-	-	-	Not known	0
Aubergine/eggplant, *Solanum melongena*	503-4	62	/chap6/eggplant.html	Bees other than honeybees	0
Chayote, *Sechium edule*	-	40	/chap6/chayote.html	Not known but insects are necessary	0
Cucumber, *Cucumis sativus*	196-201	58	/chap6/cucumber.html	Bees	0
Hot/sweet pepper, *Capsicum frutescens/annum*	499-500	110	/chap6/pepper.html	Self and bees- but not well known	0
Karela, *Momordica charantia*	208	-	/chap6/balsam.html	Bees and beetles	0
Okra, *Abelmoschus esculentus*	352-4	100	/chap6/okra.html	Self, bees, wasps, flies, beetles, birds?	0
Oyster nut. *Telfairia pedata*	-	-	-	Not known	0
French beans, *Phaseolus vulgaris*	270	24	/chap4/beans.html	Self and bees	0
Field peas, *Pisum sativum*	338-9	107	-	Self and bees	0
Pumpkin, squash, marrow, *Cucurbita*	203-7	69	*/chap6/pumpkin.html*	Bees	0
Tomato, *Lycopersicon esculentum*	492-8	137	/chap6/tomato.html	Self and large bees	0

Commodity	Free 1996 pages	Crane & Walker 1984 pages	McGregor 1976	Known Pollinator(s) from literature	Studies conducted within Africa
Fruit crops					
Custard apple, cherimoya *Annona squamosa*	129	40	/chap9/cherimoya.html	beetles	0
Apple, Malus domestica	434-45	16	/chap5/apple.html	Bees	0
Avocado, *Persea americana*	240-4	19	/chap5/avocado.html	Bees, wasps, flies	1
Borassus palm, *Borassus flabellifer*	-	32	-	Not known	0
Breadfruit, *Artocarpus altilis*	372	33	-	Not well known	0
Cape gooseberry *Physalis peruviana*	504	-	-	Not known	0
Carambola, *Averrhoa carambola*	391	35	/chap9/carambola.html	Bees and other insects	0
Citrus, *Citrus*	479-85	44	/chap5/citrus.html	Bees and other insects	2
Cherry, *Prunus avium*	431-66	41	/chap5/cherry.html	Bees	0
Date palm, *Phoenix dactylifera*	401-2	61	/chap5/date.html	Not known	0
Figs, *Ficus carica*	373-8	65	/chap5/fig.html	Fig wasps	2
Guava, Psidium guajava	386	73	/chap7/guava.html	Self, bees, other insects	0
Litchie, *Litchi chinensis*	487-8	88	/chap5/litchi.html	Bees, flies, ants and wasps	1
Mango, *Mangifera indica*	124-8	90	/chap5/mango.html	Not well understood	1
Marula, *Sclerocarya birrea*	-	-	-	Not known	0
Melon, *Cucumis melo*	190-6	92	/chap6/muskmelon.html	Bees	0
Watermelon, *Citrullus lanatus*	201-3	93	/chap6/watermelon.html	Bees	1
Natal Plum, *Carissa grandiflora*	131-2	98	-	Not known	0
Papaya, *Carica papaya*	137-9	103	/chap5/papaya.html	Hawkmoths, skipper butterflies	3
Passion fruit, *Passiflora edulis*	408-9	104	/chap5/passionfruit.html	Large bees	0
Peach, *Prunus persica*	431-66	108	/chap5/peach.html	Self and bees	0
Pears, *Pyrus communis*	431-66	108	/chap5/pear.html	Bees	0
Plum, *Prunus* spp.	431-66	113	/chap5/plum.html	Bees	0

Commodity	Free 1996 pages	Crane & Walker 1984 pages	McGregor 1976	Known Pollinator(s) from literature	Studies conducted within Africa
Fruit crops, continued					
Strawberry, *Fragaria x ananassa*	425-30	130	/chap7/strawberry.html	Bees	0
Tamarind, *Tamarindus indica*	340-1	134	-	Not known in Africa (Apis dorsata in Asia)	0
Nut crops					
Cashew nut, *Anacardium occidentale*	122-4	37	/chap5/cashew.html	Bees, flies ants	1
Macadamia nut, *Macadamia integrifolia*	418-20	89	/chap5/mac.html	Bees, wasps, beetles	0
Oil Crops					
Castor, *Ricinis communis*	226-7	38	-	Wind and bees	1
Coconut, *Cocos nucifera*	52	52	/chap5/coconut.html	Wind and bees	1
Groundnut, *Arachis hypogaea*	314-7	72	/chap3/peanut.html	Self but bees and thrips seen to increase production in Congo	1
Niger seed, *Guizotia abyssinica*	149,161	98	/chap9/niger.html	Bees but not well known	1
Oil Palm, *Elaeis guineensis*	398-401	99	/chap5/oil.html	Beetles	5
Safflower, *Carthamus tinctorius*	145-8	123	/chap9/safflower.html	Self and bees	0
Sesame, *Sesamum indicum*	410-11	127	/chap9/sesame.html	Self and bees	1
Shea, *Butryospermum pardoxum*	-	-	-	Not known	0
Soybean, *Glycine max*	325-9	27	*/chap4/soy.html*	Self and bees	0
Sunflower, *Helianthus annus*	-	132	/chap9/sun.html	Bees and other insects	3
Beverage/stimulant crops					
Cacao, *Theobroma cacao*	504-14	51	/chap5/cacao.html	Ceratopogonid midges, thrips, ants	12
Cola nut, Cola *acuminata* and *nitida*	-	81	/chap7/kolanut.html	Flies- but not well known	1
Coffee, *Coffea* spp.	475-8	53	/chap7/coffee.html	Self and bees	0

Commodity	Free 1996 pages	Crane & Walker 1984 pages	McGregor 1976	Known Pollinator(s) from iterature	Studies conducted within Africa
Fibre/container Crops					
Cotton, *Gossypium* spp.	354-9	55	*/chap9/cotton.html*	Self, but bees increase production	3
Bottle Gourd, *Lagenaria siceria*	207-8	68	/chap6/white.html	Hawkmoths, bees, bats	0
Kapok, *Ceiba petandra*	134-5	128	-	Bats, hawkmoths	1
Raffia palm, *Raphia* spp.	-	117	-	Not known	0
Forage Crops					
Acacia tortilis pods	-	-	-	Bees other than honeybees, butterflies, wasps	1?
Desmodium	-			Not known	1
Egyptian clover, or berseem, *Trifolium alexandrinum*	271-97	30	/chap3/berseem.html	Bees	7
Indigofera (browse in Africa)	-	-	-	Bees other than honeybees, small butterflies	0
Stylosanthus	-	-		Not known	0
Agroforestry crops					
Calliandra calthyrsus	-	35	-	Bees	0
Gliricidium sepium	-	-	-	Not known	0
Grevillea robusta	-	128	-	Not known	0
Leucaena leucophala and hybrids	-	-	-	Not known	0
Sesbania sesban	-	-	-	Not known	0
Cosmetics					
Bixa, *Bixa orelllana* (lipstick bush)	-	-		Not known	0
Loofah sponge, *Luffa cylindrica*	208	85	/chap6/veg.html	Moths and butterflies, possibly bees	1
Pesticides					
Mexican marigold, *Tagetes lucida*	-	-	-	Not known	0
Neem. *Azadirachta indica*	-	-	-	Not Known	0
Pyrethrum, *Chrysanthemum cinerariifolium*	148	116	/chap9/pyrethrum.html	Beetles, flies, also bees; more potent insecticide derived when flowers visited by insects	2

Commodity	Free 1996 pages	Crane & Walker 1984 pages	McGregor 1976	Known Pollinator(s) from iterature	Studies conducted within Africa
Pesticides, continued					
Rotenone, *Tephrosia vogelii*	-	136	/chap9/tephrosia.html	Not known	0
Spices					
Black pepper, *Piper nigrum*	412-13	109	/chap9/black.html	Not well known	0
Vanilla, *Vanilla planifolia*	389-90	141	/chap9/vanilla.html	Specialised bees in area where vanilla is indigenous; largely by hand within Madagascar and Africa	0

Assessments and Lessons Learned: Methods and Approaches

An initial assessment of crop dependence on pollination services in Africa was carried out in Ghana, Kenya and South Africa; three countries that are sufficiently different to capture the variation in pollination needs.

In Kenya, field assessments were carried out in on farms near Thika town in the central province, and in arid regions both near Tsavo, in the south-east, and Kerio Valley and Laikipia Plateau just north of the equator. The areas have savannah and upland forest vegetation and two rainy seasons, April-June and November. The results for Kenya are to be found in the chapters on Watermelon, Avocado, Acacia pods, Indigofera and Coffee.

Field assessments were carried out in the southwestern and central regions of Ghana in agricultural fields in clearings in the coastal rain forests. In this region, rainfall occurs throughout the year, but mainly during March to August, during which it is very wet. Flowering, however, is mostly in the dry season when pollinators are more active. The heavy, persistent rains along the Ghanaian coast inhibit pollinator activity during the wet season. The results are reported in the chapters on Mango, Cashew, Coconut, Groundnut and Oil Palm.

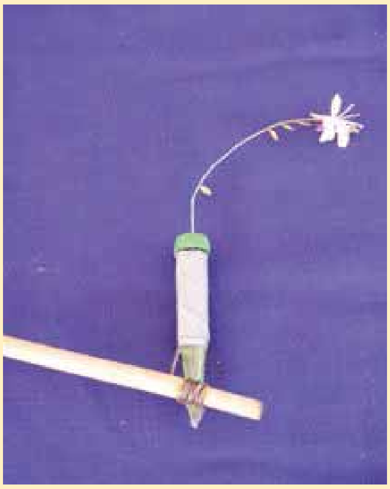
In South Africa field assessments were undertaken in the south-western region (around 34º00'S 19º00'E), among fold mountains. Here rainfall occurs in winter (June-August), and is often accompanied by snow; the summers are hot and dry. The natural vegetation is cape macchia, but it is extremely threatened and fragmented by agriculture, invasive plants and urbanization. The flowering season for crops and wild plants is mostly in spring (August to November). Deciduous fruits (peaches, plums, apricots, pears and apples) were studied to better understand their pollination needs.

All these countries have rich pollinator diversity, and where the activities took place the conservation of this biological diversity is a matter of concern. In Ghana and South Africa the work took place in Conservation International biodiversity hotspots.

Small farmers were earmarked as the primary beneficiaries of this survey, but some of the assessment was done on experimental or commercial farms. This was mainly for logistic reasons, because it is easier to plan surveys using systematically managed farms than informal systems. The crops studied are important to small farmer in the study areas.

FIGURE 3: INTERVIEW BOUQUETS

Estimating the pollination efficiency of different pollinators requires that a flower be exposed to a single pollinator visit, from which the number of pollen grains can be compared to a flower receiving no visits. Rather than wait for a specific pollinator to visit a flower, it is possible to take the flower to the pollinator. In this study, interview bouquets were used to assess the contribution of a single bee visit to coffee and watermelon. Flowers, previously bagged to ensure that no pollination had taken place, were placed in a plastic vial filled with water, that was attached to the end of a long stick.



Visual observation was used to determine what pollinates flowers. The flower visitors potential as pollinators was recorded. The categories for pollinator potential are:

(1) = almost certainly a pollinator, e.g., a regular visitor whose pollen load comes into contact with the stigma.

(2) = possibly pollinates on some visits, e.g., a regular visitor whose pollen load usually does not come into contact with stigma.

(3) = unlikely, e.g., a wasp that may carry pollen but is unlikely to visit two flowers of the same species.

In some cases pollination efficiency was confirmed using "interview bouquets" (see Figure 3).

In Kenya and Ghana, all observations of pollinators were standardised over time and space, by observing flowers for 10-minute periods, and counting the number of flowers in a 1-meter square area. This protocol has been followed in several pollination studies in Kenya and is permitting the compilation of a large database on pollination observations. Where possible, similar observations of pollinator visitation to wild plant species growing near the crop being studied were made to assess alternative forage for the pollinators, but this component of the study merits much more time devoted to it than was possible within this rapid assessment.

In South Africa, where crops known to be pollinated by honeybees were assessed, fifteen pollen-collecting honeybees were followed for five minutes and the number of blossoms visited by them during this period was counted on each of the five species of fruit trees – peaches, plums, apricots, pears and apples. The numbers and identities of other insect species visiting these same blossoms were recorded (initially at 10 minute intervals, but the dearth of such pollinators and the overwhelming presence of honeybees did not warrant continuation of this). This was to establish the comparative attractiveness of the different blossoms to honeybees and other pollinators.

Similarly, fifteen pollen-collecting honeybees were followed for five minutes as they visited the exotic weeds, *Echium plantagineum* and *Raphanus raphanistrum* growing in adjacent plots. This to establish whether the blossoms of these two weed species were more attractive to bees than fruit blossoms. Other pollinators, besides honeybees, were collected and recorded from these two weed species.

The indigenous perennial spring flowering plants growing mainly along the river banks but also interspersed between the orchards were sampled for pollinators. Ten-minute counts were also made of the number of the major pollinators visiting the most widespread of these species, viz. the Cape marigold, *Arctotheca calendula*. Similarly, the Australian *Acacia* species and the South American bugweed (*Solanum mauritianum*) were inspected for pollinators. The indigenous plants would indicate what pollinators were present and whether they also occurred on the deciduous tree blossoms and those of the exotic weed species.

The presence or absence of honeybees on the exotic weeds would indicate their beneficial or detrimental affect in allowing the build-up of colonies or by drawing bees from the possibly less attractive deciduous species.

Manageability of pollinators was determined from the known life history of the pollinator. Pollination management for agriculture has been most successful with only a few organism groups, like honey bees and leaf-cutter bees. This is because certain nesting behaviours, those that nest above ground, lend themselves better to the development of pollination management technology. Africa has several unique pollinators (like certain small carpenter bees) that have not been tried for crop pollination, but have potential because they nest above ground in hollow sticks. Taxonomists and pollination biologists together estimated the likelihood for pollinators to be managed.

This rapid assessment stressed the need to positively identify the floral visitors. Specimens were collected for identification in the course of field observation, and sent to taxonomic experts for identification down to species if possible. In addition a key to the African genera of bees was developed, and around fifteen field researchers and parataxonomists were trained in Kenya and Ghana on the use of the key.

Fruit crops: Deciduous Fruit in South Africa

Geoff Tribe

FIGURE 4: Peach trees in South Africa.

The rapid assessment of deciduous fruit in South Africa was carried out in a region that indicates the future of pollination services in Africa: it is a region that, through a combination of human disturbance and native ecology, is not rich in bees, and farmers pay for pollination services.

The south-western Cape has been intensely cultivated for about 350 years, when a refreshment station was established to service ships passing the Cape of Good Hope. The existing landscape has changed due to the introduction of European crops and farming methods, and by the introduction of many invasive weed species. Today the major crops of this region include winter wheat, grapes and fruit. Only marginal land, often on steep slopes, has not been cultivated, and much of the region has been invaded by alien plant species.

The two study sites were in the Franschhoek Valley on the farm Bien Donné, presently managed by the Department of Agriculture, and an apple orchard located at the Elgin Experimental Farm at Grabouw. The farm Bien Donné consists of peach, plum, apricot and pear orchards, with a small area devoted to the production of lavender (*Lavandula* sp.) oil. Small patches of indigenous and exotic vegetation occur around the periphery of the farm and along the river that bisects the property. On this farm were at least six natural swarms of the indigenous honeybee, *Apis mellifera capensis* Escholtz, located in oak trees, and two hives were situated near the lavender field. The Elgin Experimental Farm is surrounded by natural montane fynbos. No honeybee colonies had been brought in for pollination and what honeybees there were came from wild swarms in the vicinity.

Despite the low insect biomass in the fynbos region (Schlettwein and Giliomee 1987) and the apparent scarcity of pollinating insects, the majority of fynbos plants (about 83% according to Steiner (1987)) are insect pollinated (Whitehead et al. 1987). Despite the floral diversity of the fynbos, the region does not appear to have a particularly rich bee fauna (Michener 1979), although beetles are an important and conspicuous component of the insect pollinator fauna in fynbos (Johnson 1992). Butterflies are not common in fynbos probably because the sclerophyllous vegetation with its low nitrogen content is unsuitable for phytophagous larvae (Cottrell 1985).

Growers of apples and pears in the south-western Cape regard the presence of honeybees brought in for that purpose as essential for full pollination of the crop. This also ensures that each fruit is of a large and uniform size, and properly formed, which are essential requirements for export grade.

When flowers of some varieties are inadequately fertilized they develop into misshapen fruits, and immature fruits with relatively few seeds, which are more inclined to be shed later than ones with many seeds (Free 1970). Certain cultivars of pears are regarded as unattractive to honeybees who rapidly find more profitable forage in the vicinity of the orchard and this necessitates that a second batch of honeybee colonies are brought in midway during the blossom period. Abundant pollen is released but the nectar is not attractive because it has a low sugar content – recorded as 8-10% (Crane & Walker 1984). Most varieties of apple, pear and plum are self-unfruitful, whereas peach and apricot are largely self-fruitful (Free 1970).

Fruit farmers pay beekeepers to place honeybee colonies within their orchards to ensure full pollination. The parasitic Asian mite *Varroa destructor* Anderson & Trueman (Acari: *Mesostigmata*) which destroys honeybee brood was discovered in South Africa in 1997 and rapidly spread throughout the country (Allsopp et al. 1997). Presently the destructiveness of this mite in South Africa (Martin & Kryger 2002) is not nearly as severe as that reported amongst European races of honeybees in both Europe and the Americas. The question arises that had honeybees been totally or partially debilitated by this mite (or a disease in the future), are there alternative indigenous pollinators that could replace them?

PEACHES (*PRUNUS PERSICA* (L.) BATSCH.)

Peach blossoms (Figure 4) were almost 100% pollinated by the indigenous honeybee *Apis mellifera capensis*. A few syrphid (*Metasyrphus* sp. 1;*Ischiodon aegyptus* (Wiedemann)) and black flies (*Bibio turneri* Edwards) frequented individual flowers to obtain nectar but spent most of their time patrolling leaves and can therefore only be regarded as occasional pollinators at best. Honeybees systematically worked the flowers for the first three days after the trees began to blossom, and pollen collectors were especially frequent. After the first three days the pink blossoms began to deteriorate (after been fully pollinated) and visits by honeybees, especially pollen collectors declined rapidly. The nectar collectors then tended to move rapidly between trees and rows if no reward was forthcoming. This pattern was followed on all the deciduous fruit tree species.

All peach cultivars are self-compatible and therefore do not necessarily require pollinators, but pollinating insects are of value even for the self-fertile cultivars (Crane and Walker 1984). Peach trees originate in the Near East and as such fall within the distribution range of the Western Honeybee, *Apis mellifera.* Yellow flowers are most attractive to insects. The peach flowers do not discriminate between floral visitors (as do for example the constricted tubular flowers of some *Aloe* species) and their pollen and nectar are readily exposed.

TABLE 2. NUMBER OF BLOSSOMS VISITED BY A SINGLE HONEYBEE IN FIVE MINUTES.

Crop	Date	T range C	No. visits	Total no. blossoms visited	Mean no. blossoms visited
Peaches	06/08/03	13 – 21	15	223	14.8
Plums	28/08/03	9 – 17	15	697	46.4
Apricots	25/09/03	13 – 25	15	576	38.4
Pears	26/09/03	14 - 25	15	756	50.4
Apples	21/10/03	22 - 32	15	638	42.5
Rhamnas	06/08/03	13 – 21	15	515	34.3
Echium	06/10/03	14 - 23	15	508	33.8

TABLE 3. INSECTS VISITING THE FLOWERS OF VARIOUS PLANTS AT BIEN DONNÉ (FRANSCHHOEK) AND GRABOUW WHICH WERE SIMULTANEOUSLY IN FLOWER WITH FIVE ORCHARD TREE SPECIES. ASTERISK * DENOTES NUMBER OF ADDITIONAL PLANT SPECIES FLOWERS THEY VISITED.

FLOWERING PLANT	INSECT VISITOR ORDER	FAMILY	SPECIES
Arctotheca calendula(Cape Marigold)	Hymenoptera	Specidae	*Dasyproctus* sp.
		Scoliidae	*Campsomeris* sp.
		Andrenidae	*Andrena* sp.
		Colletidae	*Scrapter pallidipennsi* (Cockerall)*
		Colletidae	*Scrapter caesariatus* Eardley
		Colletidae	*Scrapter heterodoxus* (Cockerell)*
		Halictidae	*Patellapis (Lamatalictus)* sp.*
		Halictidae	*Patellapis (Zonalictus*) sp. 1
		Halictidae	*Patellapis (Zonalictus)* sp.2
		Halictidae	*Patellapis (Zonalictus)* sp. 3 ***.
		Halictidae	*Halictus (Seladonia)* sp
		Apidae	*Ceratina (Ceratina)* sp.
	Diptera	Bibionidae	*Bibio turneri* Edwards*
		Empididae	Sp. 1
		Empididae	Sp. 2
		Bombyliidae	Sp.
		Muscidae	*Orthelia ringiaeformis* (Vileneuve)
		Syrphidae	*Betasyrphus* sp.*
		Syrphidae	*Metasyrphus* sp. 1
		Syrphidae	*Metasyrphus* sp. 2*
		Syrphidae	*Eristalis* sp.
		Anthomyiidae	*Delia* sp.*
	Coleoptera	Phalacridae	*Olibrus sp.*
		Cleridae	*Sp.*
		Cleridae	*Dolichopsia cf. cyanella* Gorham
		Melyridae	*Pagurodactylus* sp.
		Melyridae	*Pagurodactylus angustissimus* Pic
		Tenebrionidae	*Eutrapela* sp.*
		Melolonthinae	Sp.1
		Melolonthinae	Sp.2
		Melolonthinae	Sp.3
		Melolonthinae	*Pachycnema pulverulenta* Burmeister
		Anthicidae	*Formicomus caeruleus* (Thunberg)
		Meloidea	*Ceroctis capensis* (Linné)
		Cerambycidae	Cf. *Promeces* sp.
		Buprestidae	*Acmeodera decemgutta* (Thunberg)
		Nitidulidae	*Meligethes* cf. *variabilis* Reitter*
		Dermestidae	*Attagenus* nr. *auratofasciatus* Reitter
		Dermestidae	*Attagenus* cf. *breviusculus* (Reitter)
		Chrysomelidae	Sp.
		Chrysomelidae	*Oulema erythrodera* (Lacordaire)
		Chrysomelidae	*Eurythenes* sp.
Raphanus raphanistrum (Wild radish)	Hymenoptera	Eumenidae	*Delta* sp.
		Colletidae	*Scrapter heterodoxis* (Cockerell)*
		Halictidae	*Patellapis (Lamatalictus*) sp.*
	Lepidoptera	Pieridae	*Colias electo electo* (Linnaeus)
		Pieridae	*Dixeia* sp.
		Nymphalidae	*Cynthia (Vanessa)* cardui *(Linnaeus)*
	Diptera	Empididae	Sp.1**

FLOWERING PLANT	INSECT VISITOR ORDER	FAMILY	SPECIES
		Syrphidae	*Betasyrphus* sp.*
	Coleoptera	Cleridae	*Dolichopsis* cf. *cyanella* Gorham
Zantedeschia aethiopia (Arum lily)	Diptera	Empididae	Sp.1
		Tipulidae	Sp.
	Coleoptera	Melyridae	Cf. *Troglops*
		Melyridae	*Pagurodactylus* sp.
		Cleridae	*Dolichopsis* cf. *cyanella* Gorham
		Cleridae	*Notostenus viridis* (Thunberg)
		Tenebrionidae	*Eutrapela* sp.
		Melolonthinae	Sp.1
		Melolonthinae	*Peritrichia albovillosa* Schein
		Meloidea	*Ceroctis capensis* (Linné)
		Nitidulidae	*Meligethes* cf. *variabilis* Reitter*
Cenia turbinate (Goose daisy)	Hymenoptera	Colletidae	*Scrapter pallidipennsi* (Cockerell)*
Vicia atropurpurea Purple vetch	Hymenoptera	Halictidae	*Patellapis (Zonalictus)* sp. 3***
Vicia sativa Broad-leaved purple vetch	Hymenoptera	Halictidae	*Patellapis (Zonalictus)* sp.3***
	Diptera	Anthomyiidae	*Delia* sp.*
Solanum mauritianum (Bug-weed)	Diptera	Syrphidae	*Metasyrphus* sp.2*
Lupinus luteus (Yellow lupin)	Hymenoptera	Halictidae	*Patellapis (Zonalictus)* sp.3***

The low mean number of 14.8 peach blossoms visited in five minutes is largely because of the long time taken by the bees to pack the pollen on their bodies into the pollen-baskets, and to the cold days prior to the day records were taken (Table 2). This may also be reflected in the blooms appearing in very early spring when most insects have yet to start foraging.

Plums (*Prunus domestica* L.)

Plum blossoms were pollinated almost exclusively by honeybees. The relatively large mean number (46.4) of flowers visited in five minutes by honeybees (Table 2) can partly be ascribed to the clustering of blossoms about which the honeybees clambered without having to fly to each individual blossom. An insignificantly small number of syrphid flies (*Ischiodon aegyptus* (Wiedemann)) visited flowers to collect nectar at infrequent intervals.

In Europe, honeybees are the primary pollinators because plums bloom in early spring when populations of other insect species are low. A high population of pollinators is required to produce a high fruit yield because the pollen grain must come from another compatible flower and at the right time (Crane and Walker 1984).

Apricot (*Prunus armeniaca* L.)

Honeybees were the almost exclusive pollinators of apricot flowers. The mean number of flowers visited by an individual honeybee in five minutes was 38.4, which was slightly lower than expected. In a study in Australia, honeybees comprised over 97% of insects on the flowers and improved fruit set and yield (Langridge and Goodman 1981).

Pears (*Pyrus communis* L.)

The recommended pollination strategy for the commercial pollination of pears is to bring in two waves of honeybee colonies because the flowers of many cultivars are reported to be unattractive to bees. However, the pears (early Bon Chretien cultivar) at Bien Donné proved to be so attractive to honeybees that the highest mean number of 50.4 of flowers visited by a single bee in five minutes was recorded. Honeybees again proved to be almost exclusive pollinators of pears. The pollen baskets also contained the largest accumulation of pollen. It has been recorded that the nectar of pears is not attractive because it has a low sugar content (8-10%) but supplies abundant pollen that is highly attractive to honeybees (Crane and Walker 1984).

APPLES (*MALUS DOMESTICA* BORKH.)

At the Elgin Experimental Farm at Grabouw, it was shown that 98.2% (n=1254) of the pollinators were honeybees. The other 1.8% insects occurring on the blossoms consisted of syrphid flies (5), painted lady butterflies *Cynthia* (*Vanessa*) cardui (5), blowflies (5), solitary bees (2), a twig wilter (1), a lacewing (1), a wasp (1), a blackfly (1), a housefly (1), and the carpenter bee *Xylocopa capitata* (1). But this underestimates the effectiveness of the honeybees because there is no comparison between them and these other insects in pollination efficiency. Most visitors other than honeybees visited apple blossoms only erratically.

EXOTIC WEEDS

The exotic weeds adjacent to the deciduous fruit crops were surveyed to assess to what degree they provide alternative resources for the crop pollinators. None of the Australian *Acacia* species growing along the river banks and elsewhere (within 5 to 50 metres from each orchard) were visited by any pollinators over the observation period. The Australian stink bean *Paraserianthes lophantha* attracted a few honeybees that foraged for pollen, but no other pollinators were recorded. Two exotic weed species that were highly attractive to honeybees were *Echium plantagineum* from Europe and Asia, and wild radish (ramnas) *Raphanus raphanistrum* from Europe. The mean number of flowers visited by individual pollen-collecting honeybees in five minutes was 33.8 for *Echium* and 34.3 for *Raphanus* (Table 2).

These latter two exotic weeds may be important for honeybees, and also for other members of the pollination community: adjacent to the river where *Ramnas* grew amongst indigenous vegetation, a far greater number of insect species visited these plants although honeybees still predominated. These included solitary bees, xylocopids, wasps and several small beetle species.

INDIGENOUS FLOWERING PLANTS

Indigenous flowering plants in farm margins were also surveyed to assess to what degree they provide alternative resources for the crop pollinators. The most prevalent indigenous plant flowering during this time was the Cape Marigold *Arctotheca calendula*. Other species included a *Senecio* sp., the Arum lily, *Zantedeschia aethiopia*, and yellow sorrel, *Oxalis pes-caprae.* Few of these indigenous plants were attractive to honeybees, although many- such as Cape marigold- were important resources for solitary bees and syrphid flies, among other pollinators.

CONCLUSIONS

All five species of deciduous fruit trees were thoroughly pollinated almost exclusively by honeybees, which comprised over 98% of all pollinators recorded on these trees. This is even an underestimation of the effectiveness of the honeybees because the other insects recorded on the blossoms, such as the odd *Xylocopa caffra* (Linnaeus), *Xylocopa capitata* Smith or solitary bee, although effective as pollinators, visited only a few blossoms and could in no way match the efficiency of the honeybees. The few flies (syrphids and Muscidae, *Orthellia ringiaeformis* (Villeneuve)), and beetles observed on the blossoms were only occasional visitors and inefficient pollinators and collected nectar usually without touching the anthers of the blossom.

In the course of gathering these observations, it was noted that both nectar and pollen was collected from all the deciduous fruit species except for apples where 98.2% of the foragers were collecting nectar only. This is confirmed by the fact that only honeybee colonies placed on apples for pollination purposes produce any honey (Mostert, pers comm.). The Bon Chretien pear trees were especially attractive as suppliers of pollen and the pollen-baskets of the honeybees were packed high with the greyish pollen. The pollen produced by the apples was not attractive to the honeybees.

Honeybees visited alternative floral resources at a lower rate than they visited the fruit species (except for peach). Nonetheless they clearly obtained floral resources from *Echium* and *Ramnas*, and also serve as pollinators at least of the *Echium* where they emerge from flowers coated in a film of blue pollen.

Plants originating in Europe and Asia, where *Apis mellifera* naturally occurs, did have a beneficial affect on both the Cape honeybee and several indigenous solitary bee species and produced both nectar and pollen. Not only do honeybees find *Echium* and *Ramnas* highly attractive, but so do indigenous bees which also frequent *Vicia* spp.

With the recent expansion of the fruit growing area in South Africa, there is presently a shortage of pollination units available for deciduous fruit. Part of the problem lies in the systematic removal of *Eucalyptus* trees, which were classified as invader species but were the most important source of nectar and pollen to tide colonies over the summer dearth period. So plant species that contribute to the well being of honeybee colonies are beneficial. There was no indication that honeybees were enticed away from the fruit blossoms by the exotic weeds, and the indigenous solitary bees also benefited by the presence of these floral resources.

Honeybees are indispensable as pollinators of deciduous fruit in the south-western Cape and should they be afflicted by a debilitating disease or other parasites, the export fruit industry will be severely affected. Continued efforts to document alternative pollinators, and alternative floral resources for honeybees and other potentially important pollinators, will be useful.

Watermelon in Kenya

Grace Njoroge, Laban Njoroge, and Barbara Gemmill-Herren

Kenya is within the probable area of domestication of watermelon (*Citrullus lanatus)*, yet no pollination work on the plant has previously been carried out in the region. One of the members of the African Pollinator Initiative, Grace Njoroge, is pursing a PhD on the topic of watermelon pollination in the region of Yatta. The majority of her study has focused on the behaviour and patterns of honeybee pollination of watermelon, as these are by far the predominant visitors. But through the support of the FAO Rapid Assessment project, we were able to supplement her field observations with several days of deliberate, focused observations on alternative pollinators of watermelon.

The Yatta Plateau of Kenya, to the east and below the important agricultural town of Thika, is intensely farmed by smallholders and some large estates. The region, though fairly dry, is dissected by rivers and also fortunate to have a major engineering work, the Yatta Furrow, running near the top of the ridge between two valleys, diverting water from the Thika river to farms along the plateau. Although the region is arid, the furrow permits irrigation of crops such as coffee and watermelon.

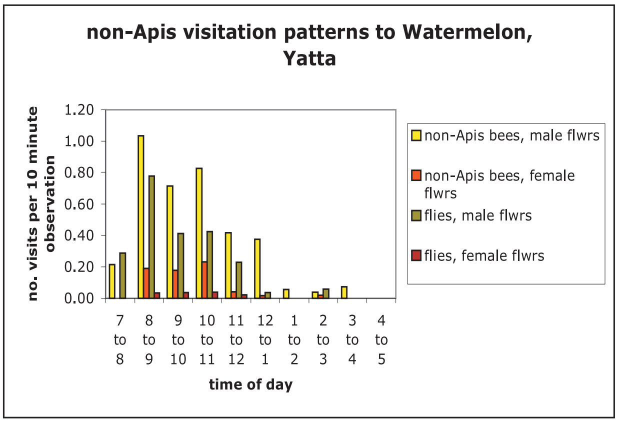


FIGURE 5: NON-*APIS* VISITATION PATTERNS TO WATERMELON, YATTA

FIGURE 6: MALE FLOWERS, WATERMELON

On both of the farms in Yatta region where information was collected on pollination, honeybees were by far the most numerous and thus important as pollinators for watermelon. Yet, the national youth service farm at Yatta where we observed watermelon pollination, does not keep bees. Thus farmers in the region rely on wild bee colonies, of which several can be seen in riparian zones on farms in this region. Unfortunately, the National Youth Farm has employed its many young workers to clear fields to the river, and have greatly reduced the riparian zones.

Female watermelon flowers are much less abundant than male flowers (Figure 6), and also appear to be less visited by honeybees. The team observing watermelon for non- *Apis* visitors thus separated observations of male and female flowers to see if this held true with other flower visitors. As with the other investigations within Kenya, watermelon flowers were observed in the field over 10-minute intervals of time, at all times of the day, and in this case over six days. The non-honeybee visitors to watermelon flowers included those in table 4.

Female flowers were considerably less frequently visited by both non- *Apis* bees and flies, as well as by honeybees (Figure 5).

TABLE 4. VISITORS TO WATERMELON FLOWERS

Order	Family	Subfamily	Genus	Species
(a) Bees				
Hymenoptera	Halictidae		*Lasioglossum*	*sp.A*
Hymenoptera	Halictidae		*Lasioglossum*	*sp.B*
Hymenoptera	Halictidae		*Lipotriches*	*sp.*
Hymenoptera	Apidae		*Apis*	*melifera*
(b) Other visitors				
Diptera	Syrphidae	Syrphinae	*Allobaccha*	*sp.*
Diptera	Syrphidae	Syrphinae	*Allograpta*	*nasuta*
Diptera	Syrphidae	Syrphinae	*Betasryphus*	*adligatus*
Diptera	Calliphoridae	Chrysomyinae	*chrysomya*	*chloropyga*
Diptera	Calliphoridae	Chrysomyinae	*chrysomya*	*sp.*
Diptera	Calliphoridae	Calliphorinae	*Hemipyrellia*	*sp.*

However, if we consider the ratio of male to female flowers (13:1), then it is evident that particularly in the case of non-*Apis* bees, the visitors are actually preferring and seeking out the female flowers. Interestingly, at least two of the non-honeybee bee pollinators in the watermelon field were found nesting in the soil of the field. If nesting habits can be observed more closely, land management practices could be prescribed to best conserve these nests on-farm.

Indigenous bees pollinating watermelon atYatta, in Kenya- aside from honeybees - show appropriate pollination behaviour, and evidently are able to make use of conditions on-farm to nest. While soil-nesting bees may be among the hardest to manage, the fact that they are already able to nest within a field suggests that management procedures to ensure their survival could be developed.

Mango in Ghana

Peter Kwapong

Mango (*Mangifera indica* L.) is one of the most important fruit crops world wide. The major producing areas of Mango include: United States of America (Florida), Mexico, Central America, West Indes (Caribbean Islands), South America (Brazil), Africa (Tanzania, Zaire), Arabian Peninsula, Asia (India, Pakistan, Philippines, Indochina and Indonesia). There are about 150 varieties of mango grown world wide. The plant is very important for its high economic value and as foodstuff for the inhabitants of the tropics. The fruits of mango are eaten fresh or canned. They are used to make fruit drinks. The unripe fruit is used in pickles. The stem bark is boiled with shea-butter and used to treat bronchial disorders in children. In Ghana, both local and improved varieties of mango are grown for local use and for export.

Mangos belong to the family Anacardiaceae. It is a large evergreen tree which can live for over 100 years. Mangoes grow best at altitudes below 1,500 metres, rainfall of 1.500 mm per year, and with very little variation in day and night temperatures.

Mango flowers (Figure 7) occur in a conical panicle up to 45 cm long depending on the variety and environmental conditions during its development. The panicle bears 500 – 600 flowers. Both bisexual and male flowers are present on the same panicle. However, their proportions depend on the variety and temperature during its development. The size of both male and hermaphrodite flowers varies from 6-8 mm in diameter. They are subsessile and have a sweet smell.

FIGURE 7: INFLORESCENCE AND IMMATURE FRUITS OF MANGOES

Mango produces relatively small amount of pollen per flower. The mango (hermaphroditic) flower is such that any organism that lands on the flower is likely to effectuate pollination. The flower opens early in the morning. Maximum pollen shedding is from about 8 am to noon. The flowers secrete nectar in considerable quantities. This attracts a large number of insects.

Table 5. Floral visitors to Mango, Ghana.

Species observed	Score	Notes
Apis melifera (honey bee)	1	Visited early from 7.30 am and took over the pollination of mango
Halictidae (*Pseudalpis* sp)	1	Collected on flowers
Dactyrarina sp (Stingless bee)	1	Collected on flowers
Wasps (9)	1-2	Collecting nectar
Syrphidae (2)	1-2	Hovering and occasionally landing on flowers
Calliphoridae	1-2	Walking over flowers
Muscidae (4)	1-2	Walking over flowers
Coleoptera (brown soft bodied)	1-2	Were many on flowers in the evening from 5.00pm
Arctiidae,,Ctenuchinae, *Euchromia sp* (Moth)	1-2	Flying over trees with occasional landing on flowers
Chrysomelidae (2)	2-3	Feeding on plant material
Dolichopodidae	3	Walking over flowers
Ichneumonidae (1)	3	Parasitoid, predating on other insects

Sites selected for research into the pollination of mango include: Dodowa, a major mango growing area and Cape Coast. These locations are in the Greater Accra and Central Regions respectively.

About 29 species of dipteran flies were collected. These seem to be the main pollinators even though bees and wasps were also found on the flowers. Apart from honeybees, 4 other bee species and 7 species of wasps were also collected from the flowers. Three species of chrysomelid beetles, and some Lepidoptera were also collected. No alternative host flowering plants were found around since the vegetation was mainly grass.

Figure 8: Male flower of Papaya

Figure 9: Female flower of Papaya

Figure 10: *Herse convolvuli* (with tongue extended) —one of the hawkmoths pollinating Papaya

Papaya in Kenya

Dino Martins

Papaya (*Carica papaya*), also known as paw-paw, is a widespread fruit crop throughout Kenya where enough water is available for it to be cultivated. It is a perennial tree crop, dioecious, i.e., separate male and female flowers, and therefore requires a pollinator in order to set fruit. In tropical and sub-tropical climates, fruit set occurs throughout the year. Papaya is sold and eaten locally as a fresh fruit, with much demand from the numerous hotels, local grocery stores and the town markets. Papaya is dried and exported as part of a dried fruit mixture. The 'milk'- a latex produced by the unripe fruit is harvested and used in the production of papain, an enzyme that acts on protein. Papain is used in the brewing industry, canned meats and medicinally. Coastal peoples also use the latex from unripe fruit to ease the pain and remove the spines and stinging cells of sea-urchins and jellyfish. The seeds are dried and exported to health food stores.

In some areas, the leaves are used to wrap meat, which is then roasted. This is said to act as a tenderiser and improve flavour. Unripe fruits are also boiled and eaten as a vegetable by some communities. Sale of fresh papaya across Kenya provides some regular income for farmers. Single fruits are sold for between 20-100 Kshs ($ 0.26-1.3), depending on the location and local abundance or availability of fruit. Most small-holder farms produce at least fifty individual saleable fruits a season.

Papaya pollination observations (Table 6) were made in multiple sites including the following: Kerio Valley, Machakos, Kitisuru (Nairobi), Kitengela and Mosoriot (Eldoret).

Table 6. Floral visitors to Papaya, Kenya

Species observed	Notes/observations/sites where present
Diptera	
Calliphoridae	Occasional diurnal visitors to female flowers. Not pollinating. (All sites studied).
Tephritidae: *Didacu*s sp.	Common diurnal visitor to female flowers. Not pollinating. May be laying eggs in young fruit. (Kitisuru and Kerio valley)
Hymenoptera	
Apidae:*Apis mellifera*	Occasional visitor to male flowers. Not pollinating. (Kerio valley)
Lepidoptera	
Hesperiidae:*Ceoliades* sp.	Occasional diurnal visitor to both male and female flowers. Some pollen transport. Pollinator. (Kerio valley)
Sphingidae: *Hippotion celerio*	Abundant floral visitor. Seen at both male and female trees. Hovers while feeding. Pollinator (Kerio valley, Machakos and Kitengela)
Sphingidae: *Herse convolvuli*	Abundant floral visitor. Seen at both male and female trees. Hovers while feeding. Pollinator (Mosoriot and Kitengela)
Sphingidae: *Macroglossum trochilus*	Abundant floral visitor. Seen at both male and female trees. Hovers while feeding. Diurnal. Pollinator (Mosoriot)
Sphingidae:*Daphnis nerii*	Abundant floral visitor. Seen at both male and female trees. Hovers while feeding. Pollinator (Mosoriot)
Sphingidae:*Nephele comma*	Abundant floral visitor. Seen at both male and female trees. Hovers while feeding. Pollinator (Machakos)
Noctuidae: *Sphingomorpha chlorea*	Occasional floral visitor. Hovers and alights on flowers. Pollinator (?) (Kitengela and Kitisuru)

The Kerio Valley had the largest stands of trees, with farms near rivers supporting hundreds of trees and supplying fruit to traders in lorries. Fruits are transported to Nairobi and other towns

The Papaya plant is a relatively fast-growing species. It reaches a height of several metres. Papaya requires pollination to set fruit. There are separate male and female flowers (Figures 8 and 9), as a rule, on separate trees. Occasionally hemaphrodite trees are found. The male flowers on 'male' trees are smaller but are produced in larger numbers than female flowers.

They are produced in small bunches on short panicles originating from the trunk in-between the leaf-bases. Female flowers occur single at the base of leaves appressed to the trunk. Both flowers offer nectar rewards to pollinators.

Given the dioecious nature of the trees, both male and female flowers were observed during this pollination assessment study. Floral production of fragrance and floral visitor activity is highest after dusk, and before eight p.m. Flowers were watched for between 30 minutes to an hour at each site studied (generally after sunset). Initial observations indicated little pollinator activity during the day. Diurnal visitors included fruit flies and calliphorid flies (female flowers). Occasional honeybees visit (male flowers) and flower moths visit (female flowers). One large species of skipper butterflies (Hesperiidae), were observed visiting during the day at one location. They visited both male and female flowers. This is important for transfer of pollen.

The pollination of the dioecious flowers is primarily carried out by crepuscular/nocturnal moths (Sphingidae). These moths, better known as hawkmoths or sphinxmoths, are fast-flying, large and highly mobile insects (Figure 10). This makes them extremely efficient pollinators. Preliminary observations on Kenyan farms show that different moth species are responsible for pollination across different sites. Pollination happens primarily after dusk, within an hour or so. This is a fairly narrow window and only the hawkmoths visit both male and female flowers at this time, and are able to cover the distances between trees and plantations quickly.

Avocado in Kiambu, Central Kenya

Wanja Kinuthia and Laban Njoroge

The avocado tree originated in Central America, where it co-evolved with native pollinators. Effective pollinators, whether co-evolved or not must be adapted to visit both male and female flower stages, coming in contact with the dehisced anthers and receptive stigma at the same pollen collection zones. Small and medium flying insects (3-8 mm in length) are especially apt to efficiently collect avocado nectar.

Avocado is currently grown in most countries in the world. According to Wysoki et al. (1997), the main avocado producing countries in Africa are South Africa, Democratic Republic of Congo, Cameroon, Kenya, Egypt and the Canary Islands. Kenya is among the top exporting countries in Africa mainly to France, Germany and United Kingdom (Collin, Pers. comm.)

The avocado flower is small and has both male and female reproductive organs. The flowers are carried on terminal panicles. Each panicle carries a few hundred flowers. All cultivars have similar flower structures though they may differ slightly in flower size.

An individual avocado flower goes through two stages. When it opens in stage I, the pistil is receptive, and pollination and fertilization can occur. The flower closes after stage I and opens again in stage II when the anthers dehisce. Avocado cultivars fit into two general types according to the time of day their flowers are in different stages. The flowers of type A cultivar are in stage I in the morning of the first day and stage II in the afternoon of the following day, so that the flower's opening cycle lasts about 36 hours. Type B cultivar are in stage I in the afternoon of the first day and stage II in the morning of the following day. The flower opening cycle lasts about 20 hours (Free 1993). A farmer with type A and B is ideal so that, in the morning, type A are pollinated with pollen from type B trees and in the afternoon, type B would receive pollen from type A.

Self-pollination is possible because flowering dichogamy is rarely absolute: opening and closing of flowers of the same tree is not necessarily perfectly synchronized. Therefore, early opening flowers may overlap with late opening ones (Free 1993). Even when self-pollination within a tree is possible, insects are needed to transfer the pollen between flowers. The three types of pollination: cross, close and self-pollination occurs in avocado. Robbertse et al. (1996) were able to demonstrate a clear advantage of cross over self-pollination.

A pollination survey was conducted on six trees of "Hass" and "Fuerte" varieties, in Kiambu District Central Province. This site was chosen because the plants had flowers at eye-level for ease of observation (Table 7).

The honeybee, *Apis mellifera* L. was clearly the most prolific visitor on avocado flowers, visiting in much larger numbers than other visitors. Honeybees appeared in the morning between 6:00 to 10:00 and never to return again until the following day. There were various species of flies observed visiting the flowers. Flower beetles and ants were also observed (Table 7). Although ants were permanently on the flowers, they appeared less effective as pollinators as they rarely came into contact with the anthers and stigma of the flower. They were also observed to deter

TABLE 7. FLORAL VISITORS TO AVOCADO IN GACHIE VILLAGE, KIAMBU DISTRICT, KENYA

ORDER	FAMILY	SUBFAMILY	GENUS	SPECIES
Diptera	Calliphoridae	Calliphorinae	*Lucilia*	sp.
Diptera	Sarcophagidae	Miltogramminae	*Hoplacephala*	*tesselata*
Diptera	Calliphoridae	Chrysomyinae	*Chrysomya*	*chloropyga*
Diptera	Sarcophagidae	Sarcophaginae	*Sarcophaga*	*inaequalis*
Diptera	Calliphoridae	Calliphorinae	*Hemigymnochaete*	*varia*
Diptera	Calliphoridae	Rhiniinae	*Rhyncomya*	*stannocuprea*
Diptera	Calliphoridae	Rhiniinae	*Rhinia*	sp.
Diptera	Anthomyiidae	-	*Anthomyia*	sp
Diptera	Muscidae	Muscinae	*Musca*	sp
Diptera	Muscidae	Muscinae	*Musca*	sp
Diptera	Muscidae	Muscinae	*Musca*	sp
Diptera	Muscidae	Phaoniinae	*Atherigona*	sp
Diptera	Muscidae	Coenosiinae	*Anaphalantus*	sp.
Diptera	Syrphidae	Syrphinae	*Allobaccha*	sp
Diptera	Syrphidae	Syrphinae	*Paragus*	sp
Diptera	Agromyzidae	-	*Melanagromyza*	sp.
Hymenoptera	Apidae	Apinae	*Apis*	*mellifera*
Hymenoptera	Braconidae	Microgasterinae	*Apanteles*	sp.
Hymenoptera	Formicidae	Formicinae	*Acantholepis*	sp

other would-be effective pollinators from visiting the flowers due to their intimidating large numbers. The ants also deplete the nectar from flowers, making other visitors spend very little time on flowers. Farmers often band their Avocado trees with appropriate products to keep the ants away. The variety of species observed on the avocado flowers in Gachie, Kiambu are shown on Table 7. However, the pollination efficiency for each species was not carried out in this study.

Though avocado is an exotic tropical fruit to Kenya, its reproduction has adapted well to the local pollinators as shown in this study. The exposed flower with large amount of nectar and pollen attracts a large number of visitors. The area of study is densely populated, where most farms are less than four acres. The farmers keep cattle in near to zero-grazing level, and are averse to bee keeping according to a survey reported elsewhere in this study. The only other flowering plants were the *Lantana* sp. hedge surrounding the farm. In spite of this, the honeybees *A. mellifera* visited the flowers abundantly followed by several genera of Diptera. Ants, flower beetles and wasps were also observed. The study should be repeated and the sampling period extended to cover the entire flowering period. It would be interesting to compare Kiambu, Murang'a and Nyeri since the later two have less degraded environment. Determination of the frequency of other indigenous bees would compliment studies done elsewhere.

NUT CROPS

Cashew in Ghana

Peter Kwapong

Cashew (*Anacardium occidentale* L) is a hardy, drought-resistant tropical or subtropical tree. In the neotropical zone, it grows from Mexico to Peru and Brazil, including Hawaii, Puerto Rico, and parts of the southern tip of Florida. Worldwide India is the leading producer: other producing countries include Mozambique and Tanzania (Mutter and Bigger 1961, Purseglove, 1968).

Even though wild cashew has been growing in various part of Ghana for over fifty years now mainly for its apple, it is increasingly being cultivated commercially in several areas around the country as an export crop. Hence cashew has become one of the most important non traditional crops in Ghana. Research is therefore need to support it successful cultivation especially in the area of pollinators.

The cashew nut is rich in protein and oil and the apple is extremely high in vitamin C (greater than 500% of US-specified Recommended Daily Allowance) and other minerals. In Ghana the nuts are processed for export as dried roasted nuts. The apple is consumed fresh as found in many local communities in Ghana or partially dried and candied.

Flowers are tiny, pinkish, borne terminally on panicles. Flowers can be male or hermaphrodite flowers on the same panicle (inflorescence). Both flower types produce pollen and nectar. The cashew fruit is a 1 inch nut, shaped like a small boxing glove, hanging below a fleshy, swollen peduncle (receptacle) called the "cashew apple", which has a value in addition to the nut. (See Figure 11).

Cashew pollination was observed at the Winneba junction in a farmer's field on the same site as coconut. The plantation covers about 200 acres, part of which has been intercropped with coconut. The field had mixed varieties of cashew, which are not too tall making sampling convenient. Pollinators from many different taxa were observed on cashew (Table 8).

There are a variety of potential pollinators on cashew in Ghana. Honey bees, leafcutter bees and the large carpenter bees offer good potential for pollinator management. However, their efficiency as pollinators needs to be studied and compared.

FIGURE 11: CASHEW FLOWERS AND YOUNG FRUIT

TABLE 8. FLORAL VISITORS TO CASHEW, GHANA

Species observed	Score	Notes
Honey bee (*Apis mellifera*)	1	Collecting pollen and are major pollinators
Green metallic bee		
(Halictidae)	1	Definitely pollinators
Megachilidae	1	Definitely pollinator
Xylocopa sp.	1	Buzz pollinator
Syrphidae	1	Pollinators
Diptera (unidentified)	1-2	Possible pollinator
Wasps(3)	1-2	Probably nectar and pollen collectors
Calliphoridae	1-2	Walking over flowers causing pollination
Oecophylla longinida (Ant)	1-2	Walking over flowers could result in pollination
Camponotus	2-3	Probably predators
Muscidae (diptera)	2-3	Probably a pollinator
Coreidae	3	Plant sucking insects
Pyrrhocoridae (cotton stainer)	3	Plant sucking insects
Mantidae	3	Predator

OIL CROPS

Coconuts in Ghana

Peter Kwapong

The coconut (*Cocos nucifera* L.) is found along tropical seashores around the world, and in some areas it is cultivated far inland. Coconut is described as one of Nature's greatest gifts to man because almost every part of the tree is used in some way. Coconut oil, extracted from the dried endosperm (copra), is unusual amongst plant oils in that it is solid below 24'^{o}C. It was the major raw material in the production of margarine in the early day of its production. In Ghana, the milk is usually a refreshing drink for most people. The soft endosperm inside the hard pericarp is a good source of fat, protein and carbohydrate. The leaflets are used for fencing and for raising temporary sheds. Along most of the fishing coasts, the stems are used to anchor small canoes or fishing boats.

The coconut plant has a tall unbranched trunk surrounded by a crown of fronds, although branched forms are occasionally found. A leaf requires 10 years to reach full size, then it will last for 2 more years. A new leaf and an inflorescence forms about once each month. The coconut is monoecious, having both staminate and pistillate florets on the same many-branched inflorescence, the 2- to 4-foot long spadix or fleshy panicle in the leaf axil. There are only a few female flower on each inflorescence and these are found together with a pair of male flowers at the base of the branches (Figure 12); most of the male flowers are borne singly or in pairs towards the branch tips. As the flowers contain nectar and are sweet scented, it is likely that insects are important for pollination. However, as the pollen is light and dry, there may also be some wind pollination. The male flowers mature and wither before the female flowers become receptive (a condition known as protandry) so that flowers in the same inflorescence cannot pollinate one another. This ensures cross-pollination. Flowering occurs on the plant throughout the year.

Coconut pollination was studied in a farmer's field at Winneba junction half way between Cape Coast and Accra in the Central region of Ghana. It consist of about 20 acres of coconut plantation, in part intercropped with cashew. Flower visitors and their behaviour on the inflorescence are summarized in the table 9.

Bees appear to be the most important pollinators, although this needs to be confirmed through pollination efficiency experiments and not just flower visitation. Both honey bees and stingless bees are social and can be easily managed in large numbers. The choice of managed pollinator should depend on their pollination efficiency and the farm structure. Stingless bees are not dangerous like honey bees and can be safely kept near farm residences.

FIGURE 12: FEMALE COCONUT FLOWERS

Table 9. Floral visitors to Coconut, Ghana.

Species observed	Score	Notes
Honey bee (*Apis melifera)*	1	Collecting pollen
Stingless bee (*Meliponula* sp)	1	Many were collected on freshly opened flowers with pollen on them
Halictidae (*Halictus* sp)	1	Pollinator
Ants (*Campnotus*)	2-3	Walking on flowers could result in pollination

Groundnut in Ghana

Peter Kwapong

Groundnut (*Arachis hypogea*) is an annual plant of the legume family. The edible seeds are called peanuts. Groundnut is also called goobers, goober peas, earthnuts, monkey-nuts and pinders. They are native of South America but are cultivated in many parts of the world, chiefly in Asia, Africa and the United States. Groundnut plants differ from other types of leguminous plants by producing their pods underground.

Groundnut serves principally as human food and livestock feed. The seeds are especially rich in oil and protein. The roasted seeds can be ground into a paste which makes a delicious spread on bread. Peanut oil extracted from the seeds can be used for cooking. The whole plant including the seeds is used as livestock feed. Plants from which seeds have been harvested are fed as hay. Peanut cake, concentrated food made from seeds that have been crushed to extract oil is also fed to livestock. Margarine, cheese, a coffee substitute, several kinds of milk, flour, medicine, cosmetics, ink, stains, dyes, glues, plastics, fibres and insulating boards can be made from peanuts. Manufacturers grind the shells (pods) into a powder which serves as an ingredient in plastics, cork substitutes, wallboards, and abrasives. Harvested plants can also be used as organic manure.

Two general types of groundnut (peanuts) are grown commercially all over the world. These are: bunch or erect (upright) type, which is about two feet high and matures in 3 to 30 months, and the vine-like runner, creeping or prostrate type, which is about one foot high and branches two feet long on the ground. This latter type matures after 4 to 5 months and has large seeds. Both types of plants have thickening stems and small yellow flowers (Figure 13). Generally, flowers are produced near the ground on bunch plants and along the runners of the vine-like types. Each flower puts out a sharp stalk called peg. The flower buds open at sunrise. Fertilization takes place during the morning and the flowers usually wither about noon.

Within a few days the pegs (stalk stems of the pods) begin to grow. They grow slowly at first, but gradually grow more rapidly. The peg enters the ground and the pod grows from its tip. The tough, fibrous pod is about one to two inches long when matured. In most commercial varieties, each pod encloses two, sometimes three seeds.

Apart from the bunchy and runner types numerous intermediates exist. The runner types are more widely grown in West Africa. In this research the variety that was sampled was the runner type.

FIGURE 13: GROUNDNUT IN FLOWER WITH FLOWER BEETLE FEEDING ON PETALS

TABLE 10. FLORAL VISITORS TO GROUNDNUT, GHANA.

Species observed	Score	Notes
Halictidae (*Pseudapis* sp)	1	Moved very fast and spent less than 10 seconds after entering a flower
Halictidae (*Lipotriches* sp)	1	Definitely a pollinator
Caliphoridae (dipteran fly)	2-3	Possible pollinator
Flower beetles Meloidae (*Decapotoma* sp)	2-3	Eating corolla, stamens and style

Groundnut pollination was observed in Cape Coast in the Central Region of Ghana, and Northwest of Accra, the capital city. The area is mainly made up of coastal savannah and groundnut is not a major crop of the area. However, a few people grow the crop on a very small scale. Insect visitors to groundnut flowers are recorded in Table 10.

Flower beetles (*Decapotoma* sp) were found eating petals including stamens as well as styles in some cases. The flower beetles were seen on peanut flowers as early as 7.50 a.m. Few were found on the flowers initially but population increased with time especially from 9.00 a.m. onwards when flowers (keel) began to open. It appears that groundnuts are mainly self-pollinated.

The flower beetles were also found and collected from the flowers of the following plants: *Spigelia* sp., *Merremia tridentata*, *Sida acuta*, *Aspilia africana*, *Commelina benghalensis*, about 500 metres away from the sampling site.

Leaf beetles were also collected on the plant but were not pollinating. Ladybird beetles were seen feeding on aphids on the stems. Three bee species belonging to the family Halictidae and an unidentified bee were collected from the keel and are probably the main pollinators. Stalk-eyed shoot flies were also collected, along with two other fly species. Damsel flies were observed on flowers but are apparently not pollinators.

Halictidae, which are small ground dwelling bees appeared to be the most important pollinators of groundnut. It will be difficult to increase their population size through management. As it appears as if bees are the most important pollinators of groundnut, a survey should be carried out in another area to see if the bees that visit the crop differ, and perhaps more manageable species occur elsewhere.

Oil Palm in Ghana

Peter Kwapong

The oil palm (*Elaeis guineensis* Jacq.) is a tree crop believed to originate from West Africa. It is cultivated in other regions of Africa, in Asia, East and West Indies and South and Central America. In Ghana, oil palm is grown in six of the ten administrative regions. The oil palm is a high-yielding vegetable oil crop. It produces oil from the mesocarp of the fruit as well as from the kernel. The uses of oil palm include manufacture of cooking oil, margarine, soap, cosmetics and other industrial uses. In Ghana, palm leaves are used for building temporary sheds. Mid-ribs of leaflets are put together into brooms. Leaf stalks are used for weaving baskets. Palm wine is obtained from felled old stems.

Palms may reach a height of 30 meters in high forests; in other areas they are between 15 to 18 meters tall. The oil palm is monoecious; male and female flowers occur separately in male and female inflorescences on the same plant. Occasionally, hermaphrodite flowers occur. An inflorescence is a compound spike held on a stout peduncle. Spikelets are spirally arranged around a central rachis. Each inflorescence contains thousands of flowers.

Oil palm requires adequate pollination to set fruit. Though both male and female inflorescences occur on the same plant (Figures 13 and 14), cross-pollination is necessary because the inflorescences on a plant are seldom simultaneously receptive.

FIGURE 14: FEMALE INFLORESCENCE, OIL PALM

The study sites for this assessment were oil palm plantations at Jukwa and Abrafo, both in the Central Region of Ghana. Observations were made on both male and female inflorescences for visiting insects. Some insects were caught with sweep nets but the structure of the palm and position of flowers limit the use of nets. It was more effective to shake the inflorescence and collect insects in a receptacle. Insects so far collected (from male flowers) are listed in Table 11.

FIGURE 15: MALE INFLORESCENCE, OIL PALM

Though these collections were from male flowers only, the beetles are known from previous work to that the main pollinators of oil palm. About four species of small beetles were collected on male inflorescence as major pollinators. Three bee species and

TABLE 11. FLORAL VISITORS ON OIL PALM, GHANA.

Species observed	Score	Notes
Oil palm weevils (Curculionidae)	1	Main pollinators (100s of them)
Nitudilidae	1	Pollinator
Honey bee	2-3	Many bees collecting pollen
Megachilidae	2-3	Few with pollen under abdomen
Halictidae	2-3	Few to many collecting pollen
Thrips	2-3	Probably pollination
Wasps	2-3	Collecting pollen

one wasps species were also collected. All the bees as well as the wasps had pollen on their bodies but their role in pollination is unconfirmed, as they are not known to visit female inflorescence. Further work is required to correctly identify all pollinators and ensure their conservation. Being indigenous to West Africa, the origin of the oil palm, their conservation is in the interest of the oil palm and palm oil industries world wide.

BROWSE
Acacia pods in Kenya

Dino Martins

The Umbrella thorn (*Acacia tortilis*) is a spiny acacia (Mimosoideae), usually a shrub to a large spreading tree in Kenya. It is among the most drought resistant acacia species and grows with 200-900mm of rainfall. Its pollination was observed primarily in the Kerio Valley, Northwestern Kenya, where these trees are typically large and spreading forming extensive woodlands.

The trees' branches are armed at each node with a straight white thorn as well as two short grey sharply recurved spines, and the small leaves are closely spaced, making the tree densely leafy. Umbrella thorn flowers are in white, cream or sometimes pale yellow capitate heads.

Acacia tortilis is in many ways a tree of high, and sometimes unrecognised potential. Products are derived that directly or indirectly contribute to pastoral communities' livelihoods and survival in times of extreme drought. The main use in the Kerio valley is collection of pods for livestock fodder. These are additionally transported out of the valley and into the adjacent highlands where they are sold to people with livestock as a supplement food for goats, sheep and cattle.

Ripe fresh pods are eaten but the seeds are normally discarded, except in times of extreme food shortage. Then seeds are eaten as well. The crunchy pods have a faint sweet taste. Besides the pods the gum can also be eaten but is of inferior quality, is sticky and may cause choking. It is a typical famine food and a last resource in Somali Region of Ethiopia where it is collected by children and women when other foodstuff gets scarce. Pods are collected and eaten by peoples inhabiting the Kerio valley and Lake Turkana Basin of Kenya, as well as throughout the Samburu and North-eastern districts. When rains fail or are insufficient for a number of other wild foodstuffs to grow, seed-pods from *A. tortilis* are a secure food than can be picked at the end of a severe drought period. Furthermore, the inner bark can be chewed to relieve thirst and the bark is also used medicinally.

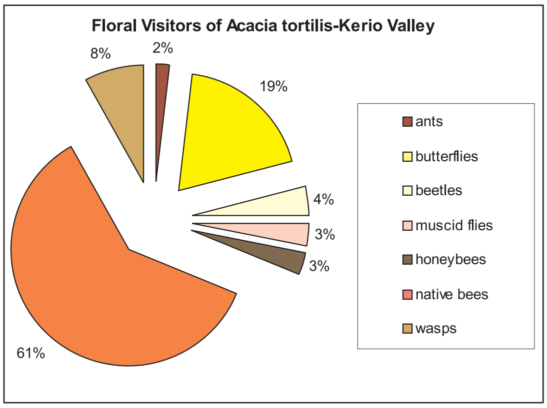


Figure 16: Percentage Types of Floral Vistors to *Acacia tortilis*, Kerio Valley

The main use of the seedpods from this acacia as a supplementary feed/nutritional supplement to livestock- primarily goats, sheep and cattle. This is where effective pollination is crucial. Hundreds of Keiyo and Pokot women (mostly) throughout the western and central areas of the Kerio Valley gather the pods when ripe/semi-ripe. The pods are shaken from the tree using a long notched stick. In some cases young boys climb half-way into the tree and aid in dislodging the pods. The pods are then collected by hand from the ground and packed

Figure 17: *Acacia* Flowers

into sacks. These are transported by donkey or on lorries to the town centres of Biretwo and Iten, where they are sold. The price per sack of acacia pods ranges from 100-200 Kshs ($ 1.3 – 2.6). Most of the pods end up being fed to livestock in the adjacent highlands, where heavy rainfall has resulted in leached soils and consequently mineral-deficient grazing and browse. Pods, once dry, can be stored in sacks for many months, and are fed to livestock in handfuls each day.

TABLE 12. RANKING OF EFFECTIVENESS- *ACACIA* VISITORS.

Group under consideration	Score
Native bee/wild bee species	1
Honeybees- *Apis mellifera*	1
Syrphid flies	2
Butterflies, moths (and Microlepidoptera)	2
Wasps	2-3
Ants	3
Beetles	3

Herders and household with large numbers of livestock will also drive the stock under certain tree that are heavily-laden with pods and then shake the tree to loosen the pods for the animals to eat. The two main periods of pod harvest are a couple of months after each rainy season (flowering) mainly in July-August and December-January.

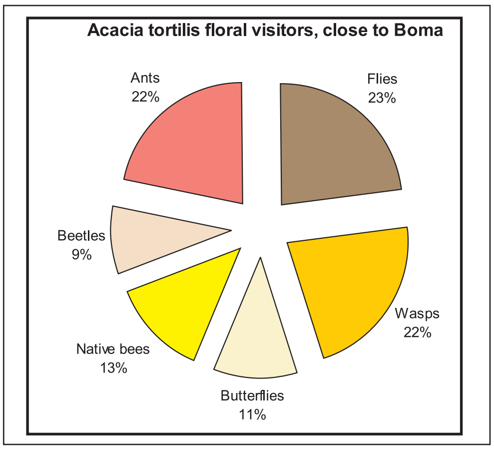


FIGURE 18: PERCENTAGE TYPES OF FLORAL VISTORS TO ACACIA TORTILIS, CLOSE TO **BOMAS**

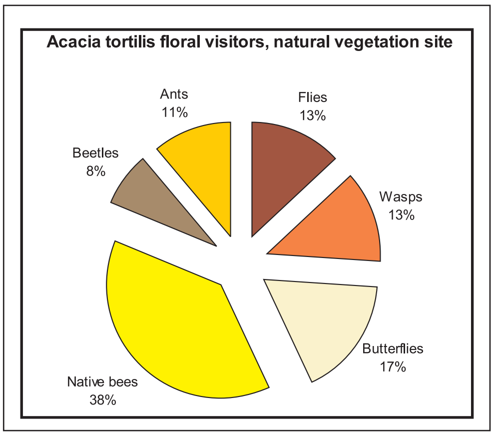


FIGURE 19: PERCENTAGE TYPES OF FLORAL VISTORS TO ACACIA TORTILIS, NATURAL VEGETATION SITE

The inner wood of dead trees oozes a dark sap that is used by the Borana peoples of northern Kenya as a source of perfume. The wood is crumbly and highly aromatic with a spicy-sweet scent. It is harvested and widely traded in markets throughout the region. The local name for the perfume from *Acacia tortilis* is "Foras".

Fuel wood and charcoal prepared from this species are widely sold on local markets and along commercial tracks throughout Kenya and in the Somali Region. The charcoal from this and other acacia species is in high demand and considered of the highest quality for roasting meat.

Umbrella thorn pollination was investigated in the Kerio Valley, Northwestern Kenya, East Africa, with additional observations made in the southern Great Rift Valley, near Olorgesailie.

The flowers of umbrella thorn are borne singly or in small axillary groups distributed on all the outer branchlets and twigs (Figure 16). They flowers are capitate (spherical) and generally off-white or pale ivory in colour. As with many species of acacias, pollen dehiscence is controlled by the tree, with a distinctive peak in dehiscence that corresponds to a peak in floral visitors and consequently pollinator activity.

In the Kerio Valley, the flowers were observed to begin to open after sunrise. Pollen dehiscence began around 11.00 a.m. and peaked later between noon and 2.00 p.m. This period of dehiscence is later that observed further south in Mkomazi, Tanzania, where trees peak dehiscence between 7.30 a.m. and 9.00 a.m. (Stone et al. 1996).

Individual capitate flowers actually consist of many tiny flowers, densely packed to form the spherical blossom. The anthers are arranged in a thick bunch, radiating outward from the floral cup. Stigmas vary in number and are also variable in protandry and distribution within and across flowering trees. Nectar was assumed to be present, given the presence of large numbers of nectarivores, including butterflies and sunbirds, that were seen actually feeding from flowers. Some captured lycaenids squirted droplets of moisture and this was also taken as an indication that the flowers contained some amounts of nectar.

The capitate flowers are easily accessed by a large number of animals, primarily insects. Most insects land on the flowers directly and move around from flower to flower once on a flowering tree. This movement and behaviour, as well as the morphology of the potential pollinators, are the primary factors used in assessing pollination in this species. Following is an analysis of the floral visitors, in terms of diversity, trends, patterns and their efficacy as pollinators.

A wide range of insect species are visitors to *Acacia tortilis*. Floral visitors include species of bees, ants, wasps, butterflies, moths, sunbirds and beetles (Figure 17). From this chart, it can be seen that Wild bees (native bee species other than honeybees) form the bulk of visitors to this acacia. Native bees account for 61 % of the total visits to *Acacia tortilis* when compared directly against the numbers and frequency of all other insect visitor taxa.

Insect floral visitors were also observed at length at another site, the southern portion of the Great Rift Valley, near Olorgesailie. Here, as in the Kerio Valley, *A. tortilis* forms an important part of the woody vegetation. Trees at two distinct sites were studied. One located adjacent to a pastoralist homestead (boma), where most of the natural vegetation other than the individual *Acacia* trees had been removed. The ground cover was mostly eaten by the livestock and most of the ground was bare and rocky. The second site where pollination observations were carried out on this species was located in an area relatively undisturbed and with many other species of plants in flower. A distinct difference was noted in the floral visitors between the two sites, as illustrated in Figures 18 and 19. The site with lots of natural vegetation, in particular other flowering plants, had far more diversity of native bees, than the site where most other natural vegetation had been removed.

Based on the criteria developed for scoring insect visitors as pollinators, careful observations of each major group, across all sites, yielded the scores recorded in table 12. For the most part, wild bee species were seen to spend the longest time on the tree's flowers and moved among inflorescences and between flowering trees. Native bee species were also found to carry the most pollen on their bodies, where it was available for pollination.

Butterflies and honeybees also spent time on flowers and their pollen loads were seen brushing floral parts. It is important to note that most butterflies studied, mainly lycaenids (which form

TABLE 13. FLORAL VISITORS TO *ACACIA TORTILIS* BLOSSOMS, KENYA

Floral visitor group	Observations/behaviour
ANTS:	
Camponotus sp.	Seen patrolling branches, scavenging opportunistically, occasionally see on flowers
Crematogaster sp.	Many thousands of this genus seen on some trees, no major flower visitation observed.
Technomyrmex sp.	Large numbers of this species seen periodically in disturbed sites, seen attacking other insects on tree.
BEETLES:	
Buprestidae: *Sternocera orissa*	Small groups of these large beetles were seen feeding amongst flowers, pollen transported on ventral surface of abdomen.
Cerambycidae: *Promeces* sp.	Seen perched on flowers.
Scarabaeidae: Rose chafers- *Pachnoda* spp.	Feeding on flowers, little pollen observed on bodies
Scarabaeidae: Rose chafers-*Rhabdotis* sp.	Feeding on flowers, little pollen observed on bodies
Scarabaeidae: Rose chafers-*Cyrtothyrea* sp.	Feeding on flowers, little pollen observed on bodies
Lycidae: *Lycus*spp.	Feeding on flowers, little pollen observed to be carried.
FLIES:	
Asilidae: robber flies	Perch on branches and hunt floral visitors
Bombyliidae: bee flies*Notolomatia* sp.	Common floral visitors, some pollen present.
Syrphidae:*Phytomia* sp.	Very common at some sites. Tend to visit trees before pollen dehiscence begins. Limited pollen transport.
Syrphidae:*Allograpta* sp.	Very common at some sites. Tend to visit trees before pollen dehiscence begins. Limited pollen transport.
Syrphidae:*Eristalis* sp.	Very common at some sites. Tend to visit trees before pollen dehiscence begins. Limited pollen transport.
Milichiidae: Jackal flies	Seen scavenging near crab (flower) spiders with prey.
Calliphoridae:*Chrysomya* sp.	Visiting flowers, common in areas near homesteads, no significant pollen transport.
BUTTERFLIES AND MOTHS:	
Scythrididae: flower moths	Common on flowers, diurnal moths, little pollen transport
Sphingidae: Hawkmoths *Macroglossum* sp.*Cephonodes* sp.	Fairly common visitors, hover while feeding so little opportunity of collecting pollen on body from capitate flowers.
Ctenuchidae: handmaidens	Seen visiting flowers, stay high in trees
Agaristidae:*Utetheisa* sp.	Occasionally observed on flowers

continued..

TABLE 13. BEHAVIOUR OF FLORAL VISITORS ON *ACACIA TORTILIS* BLOSSOMS, CONTINUED

Floral visitor group	Observations/behaviour
Hesperiidae : skippers *Spialia* sp. *Coeliades* sp.	Active feeders, moving around, heavy-bodied and seen to carry a little pollen.
Nymphalidae: *Danaus chrysippus, Junonia oenone, Junonia hierta Hamanumida daedulus, Hypolimnas misippus, Byblia ilythia*	All fairly common, some pollen transport.
Lycaenidae: *Azanus* spp.	Very common at some sites, feeding at flowers. Larvae recorded on *Acacia* leaves. Adults also roost on acacias. Little pollen transport evident.
Lycaenidae: *Cacyreus* spp.	Common on flowering trees. Little pollen transport evident.
WASPS:	
Chalcididae: *Hockeria* sp.	Parasitic wasps, occasional visitors to acacia flowers, more common amongst surrounding herbaceous flora
Scoliidae	Common, patrolling underneath flowering trees
Chrysididae	Regular visitors to flowers. Little pollen seen on bodies.
Tiphiidae	Common, patrolling underneath flowering trees
Pompilidae: *Cyphononyx* sp. *Hemipepsis* sp.	Regular and noticeable visitors, more common at trees in Rift near bomas.
Vespidae: *Polistes* spp.	Very common floral visitors, little pollen movement.
Eumenidae: *Anterhynchium* sp. *Delta* spp.	Regular floral visitors, hunt on and around flowering trees.
Sphecidae: *Ammophila* spp.	Common floral visitors, seen hunting on tree, little pollen transport. Moves rapidly amongst flowers, barely stopping.
BEES:	
Apidae: *Xylocopa somalica*, *X. inconstans*, *X. nigrita*, *X. caffra*	Common visitors to flowers. Transport of large pollen loads (amongst the largest recorded), move large distances between trees.
Apidae: *Hypotrigona* spp.	Very abundant visitors at some sites. Spend long time on flowers, good pollen loads.
Megachilidae: *Megachile* spp.	Very common floral visitors, move systematically and thoroughly over open flowers. Pollen loads large.
Apidae: *Amegilla* spp. *Anthophora* spp.	Regular visitors to flowers, good pollen transporters
Thyreus sp.	Regular floral visitor, some pollen observed.
Allodapula spp.	Abundant, spend time on flowers, carry pollen.
Apidae: *Ceratina* sp.	Common visitors to flowers. Pollen transport clearly evident.
Braunsapis sp.	Common floral visitors. Spend time crawling over flowers. Pollen transport evident.

continued.

TABLE 13. BEHAVIOUR OF FLORAL VISITORS ON *ACACIA TORTILIS* BLOSSOMS, CONTINUED

Floral visitor group	Observations/behaviour
Apis mellifera	Common floral visitor in some sites, often does not visit during peak pollen dehiscence due to temperature constraints. Good pollen transport when present.
Tetraloniella spp.	Occasional visitors, good pollen transport.
Macrogalea candida	One of the most abundant native bee visitor species, good pollen loads. Spends time on flowers.
Halictidae:Nomia spp.	Common floral visitors, transport large amounts of pollen.
Lipotriches sp.	Common floral visitors, transport of pollen evident.
Pseudapis sp.	Common floral visitors, often seen rising into air from flowers to comb pollen from body.
Lasioglossum sp.	Common floral visitors at some sites. Good pollen transport.

the bulk of lepidopteran floral visitors), actually carried miniscule amounts of pollen. Syrphid flies carried little pollen, but did spend time moving about the flowers.

Wasps varied in number and diversity from site to site, but included both solitary and social species. Some wasps spent more time on the flowers than others. Many wasps were opportunistic visitors to the flowering trees, seeking both nectar and preying on other insects. Ants and beetles were the least effective floral visitors based on the criteria of pollen loads and movement. Many beetles simple ate the flowers, despoiling them for other potential pollinators. Only large buprestids were found to carry much pollen, but these tended to stay on a single tree for a long time.

Table 13 summarises the diversity of floral visitors to *Acacia tortilis* and notes on their behaviour and efficacy as pollinators.

Native bees species, analysed in terms of behaviour, pollen loads, pollen movement and abundance and distribution are the primary pollinators of *Acacia tortilis* at all sites studied. Native bee diversity is directly proportional to pollination success on this species. Much more work needs to be done on bee diversity in relation to seed set and pollination on acacias. It is unlikely that technologically advanced pollination will be managed for *Acacia tortilis* because a food source for stock during particularly drought periods for poor farmers. However, most of the important pollinators nest in dead wood, making room for low-tech pollination management in that farmers that depend on this resource should not denude the areas of dead wood.

Indigofera (Dwarf Rangeland Browse Shrubs) in Kenya

Barbara Gemmill-Herren

In arid and semi-arid ecosystems, grasses dominate the herbaceous layer, but particularly on sites with deeper soils other forage is important. On sites with good soils about 7 kg/ha/y of forage may be produced for each mm of rainfall. In the dry season, browse that is high in protein forms a critical part of the diet for both livestock and wildlife. Dwarf shrubs form a large part of the browse in livestock and wildlife diet. Among the most important of dwarf shrubs in this Kenyan rangeland ecosystem are the Indigoferas: *Indigofera spinosa*, *Indigofera volkensii*, and *Indigofera cliffordiana* among others, and *Barleria*.

In the north of Kenya, studies tracing the human food obtained as livestock products back to the plant community responsible for their production reveals the importance of browse in this system. Dwarf shrubs, particularly *Indigofera spinosa*, were the most important component of the plant community, being ultimately responsible for 43% of the energy consumed by humans (Swift, Coughenour and Atsedu 1996).

The responses of shrubs to grazing have been less studied than that of grasses. Work in south Turkana on *Indigofera spinosa*, however, reports that at even fairly high levels of herbivore removal, no depression in aboveground production or nitrogen yield was found. This is not to suggest that rangeland can be continuously overgrazed. Many of the dwarf shrubs, such as *Indigofera* and *Barleria,* are short-lived perennials which means that their persistence depends on successful reproduction. Since neither reproduces vegetatively, their reproduction depends on effective pollination and reproduction by seed.

FIGURE 20: *INDIGOFERA* BLOSSOMS

FIGURE 21: STINGLESS BEE NEST ENTRY TUBE

Some information is known about the pollination of species within the genus *Indigofera*, not because of its browse value, but because some species are cultivated as a source of indigo dye: *Indigofera arrecta* A. Rich, and *Indigofera tinctoria* L. var. *tinctoria*. In both species, the flowers are bisexual and seed is set only if visited by bees. Extensive cross-pollination seems to result in better seed set (Howard and Howard 1915, Howard et al. 1919).

Indigofera (Figure 20) is a species that may rapidly build up to dominate the understory of arid woodlands, such as the Tsavo ecosystem, in years following heavy rainfall. In the year after the heavy rains of La Niña in Kenya (1998), people working on Rukinga Ranch remember vast hectares of *Commiphora* woodland turned pink with *Indigofera* blossoms under the tree canopies.

Table 14: Floral visitors to *Indigofera* spp. on Mpala and Rukinga Ranches, and also near Muranga, south of Sagana were:

Family	Genus and species
Halictidae	*Nomia theryi*
	Lipotriches sp. 3
	Lipotriches sp. 4
	Lipotriches sp. 6
	Lipotriches sp. 7
	Pseudapis sp.1
	Nomia sp.
Megachilidae	*Heriades* sp.
	Pachyanthidium sp.
Apidae	*Ceratina* sp.
	Hypotrigona sp.
	Liotrigona sp.

It is interesting to inquire how a species, dependent of bees for seed set and seed set for dispersal, can build up so quickly under favorable conditions; in particular, the pollination community must somehow manage to cover the resource adequately for this to occur.

Dwarf shrub species of the genus *Indigofera* have been observed at Mpala Research Center in the Laikipia Plateau of Kenya; an area of great importance both to livestock production and wildlife populations. Indigofera was also observed on Rukinga Ranch, Taita District, which forms a critical wildlife migration corridor between the Tsavo East and Tsavo West. Ranches in this area are used for fattening cattle brought from Somalia for sale in Nairobi, and thus the graze resource is of high economic importance.

Non-*Apis* bees make up the vast majority of visitors. All visitors appeared to handle the flowers properly and should be considered pollinators (Table 14)

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One population of stingless bees that visited *Indigofera* flowers in Rukinga were found nesting in a tree next to the patches of flowers (Figure 21).

The average number of flowers visited by pollinators to *Indigofera*, per 10-minute observations period was about half a flower, due to the many observation periods with no visitors. The overall visitation rate for *Indigofera* is far lower than mass flowering species such as *Acacia*, or densely flowering crops such as coffee. Visitation rates were not strongly affected by the number of flowers in a patch; in fact higher average visitation rates occurred on patches of 10 flowers or less, than for patches of 10 flowers or more. While this correlation is not strong, it does indicate that *Indigofera* is not a flower that attracts masses of generalized pollinators over short periods of time. The indigofera flowers are not strongly scented and must be tripped by an insect, and are therefore more likely to be attractive to specialized pollinators that know how to "work" the flower.

The successful reproduction of *Indigofera*, with its dependence upon pollinators, highlights the critical but unseen ways in which pollination underpins ecosystem health. The importance of dwarf shrubs such as Indigofera ripple throughout the ecosystem, fixing nitrogen to improve soil fertility and providing important browse to livestock and thus food security for people, as well as browse and cover for wildlife in savanna ecology.

This small sample of *Indigofera* pollinators highlights the importance of non-*Apis* bees. The diversity, particularly of halictid bees visiting *Indigofera* flowers is striking; taxonomic experts think there may be new species amongst those gathered in this preliminary assessment. The ability of rather specialized bees such as the Lipotriches to presumably build up in number during seasons of high rainfall to provide sufficient pollination services to Indigofera so that the shrub can vastly expand its cover remains an interesting puzzle, and one whose answer might help us to understand the resilience of arid ecosystems. *Lipotriches* have been thought, at one time, to be rather specialized on harvesting grass pollen (Immelmann and Eardley 2000), but further observations are finding that *Lipotriches* species exploit a wide range of floral resources, including crops such as watermelon and groundnut. What we do not know until more taxonomic work can be done on *Lipotriches* is how specialised each individual species is on particular floral resources.

A variety of bees visit *Indigofera.* Their nesting habits include social nests in cavities, solitary nests in hollow sticks and wood borer burrows in wood, and burrows in the ground. Effective pollination management for an indigenous shrub species such as *Indigofera* involves maintaining a healthy, natural ecosystem.

BEVERAGE CROPS

Coffee in Kenya

Wanja Kinuthia, Laban Njoroge, and Barbara Gemmill-Herren

Coffee is by far the most important cash crop throughout eastern and central Africa. It is a commodity that provides the major source of foreign exchange for many countries in the region, and supports the livelihoods of millions of smallholder farm families. More than 80% of the coffee produced in East Africa is produced by an estimated 10 million smallholder coffee farmers. In Kenya alone, 18,000,000 farm families rely on coffee for income, and the coffee produced amounts to 140 million USD.

Despite its economic importance to the region, coffee production in the region is declining, from a high of 8 million bags in 1983 to the current average of 6 million bags per year, amounting to less than 6 percent of the global coffee market. A major factor in this decline is the abolition of economic clauses of the International Coffee Agreement (ICA) and the consequent collapse in prices leading to reduced husbandry; although other contributing factors include social, economic and political issues. In many places, the prices now received by growers are insufficient even to enable them to maintain the trees. There is a renewed interest in the region, however, for the development of specialty coffee markets, to obtain premium prices for excellent quality coffee from the region, for organically and fair-trade produced coffee, and for biodiversity-friendly coffee grown under shade trees.

The question of whether bees are important for coffee production has been fairly well resolved by recent research.

FIGURE 22: HONEYBEES ON COFFEE

FIGURE 23: BAGGED COFFEE INFLORESCENCES

FIGURE 24: COFFEE PLANTATION AND RIPARIAN FOREST, WITH WILD HONEYBEE HIVES

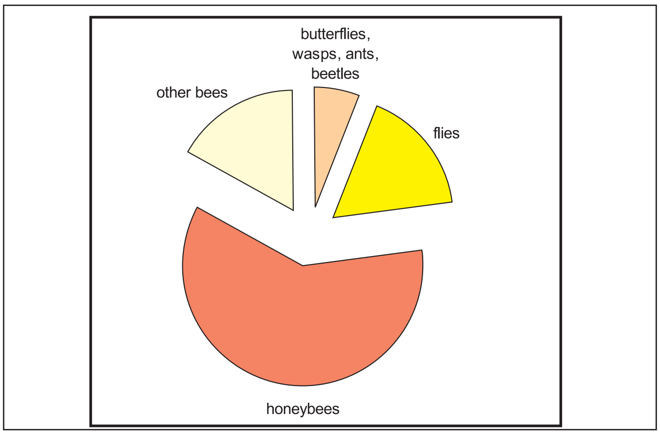

Figure 25: Percentage Types of Floral Visitors to Coffee over total observation period of 18.2 hours, Multiple Sites, Kenya

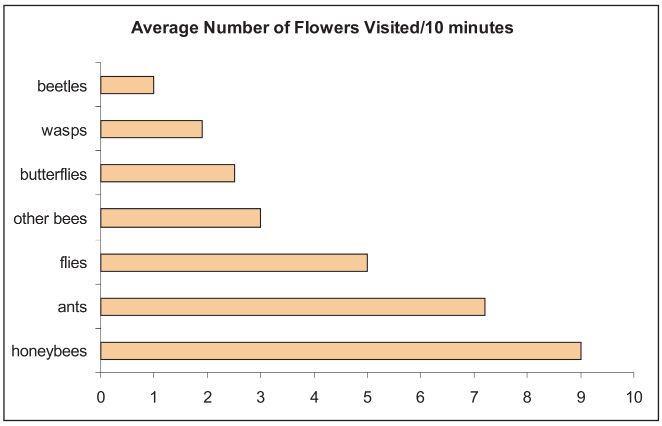

Figure 26: Average Number of Flowers visited by Taxa, over 10-minute periods

Traditionally, coffee was considered to be self-pollinating, but recent research in both Costa Rica (Roubik 2002) and in Indonesia (Klein et al. 2003) have shown conclusively that animal pollination contributes substantially to coffee yields. In Costa Rica, two varieties showed over 25% fruit retention increases from pollinating visits by bees. In one variety, coffee berries were over 25% heavier and developed faster from open pollination. The yield benefit from open pollination, chiefly by feral African bees, was 56%. In Indonesia, self pollination accounted for only 10- 60% of the yields obtainable by open or deliberate cross-pollination. In Costa Rica, feral Africanised honey bees were the principal pollinators of coffee, making it all the more ironic that coffee pollination has not been studied in the centre of origin of the crop (Ethiopia-Kenya). Up until the present, pollination has not been a subject of research at institutes such as the Coffee Research Foundation in Kenya.

Coffee flowers were observed in Sasini, Twin Rivers Farm in the Yatta region, and the Coffee Research Foundation in Riuru, Kabete, and Thika. On both of the farms in Yatta region where information was collected on pollination, honey bees were by far the most numerous and thus important of pollinators for both coffee and for watermelon. Yet, the coffee estate where observations were made does not keep bees, out of fear that the honey will be stolen.

Thus farmers in the region are relying on wild bee colonies, of which there are several. On the coffee estate, bees had formed a nest in the thicket of grasses and woody plants where the land was too swampy to farm, and also had established nests high up in riparian trees near the river. (Figure 24). One of these nests had just been attacked by a honey badger, attesting to the high on-farm biodiversity in the area (along with buffalo said to live in the swamp).

Unfortunately, the owner of one coffee whera pollination observations were carried out was determined to plant as much acreage as possible to coffee, and had labourers removing all riparian vegetation on several streams, right to the edge of the water- in contravention to Kenyan land-use law. It is unlikely that the farm would be managed in this way if the land managers understood the importance of wild spaces on farm, as nesting sites for pollinators.

Another potential source of pollinators, both honeybee and non-honeybee, is the few protected areas in the region. In this intensely cultivated region, protected areas tend to be rocky, low fertility inselbergs or outcroppings.

Table 15. Floral visitors to coffee, Kenya

Family	Genus and species
Collectidae	*Hylaeus (Nothylaeus)* sp.
	Hylaeus (Deranchylaeus) sp.
Halictidae	*Lasioglossum (Dialictus* sp.)
	Sphecodes sp.
	Lipotriches sp.
	Halictus (Seladonia) sp.
	Pseudapis sp.
Apidae	*Braunsapis fascialis* (Gerstaecker)
	Braunsapis rolini (Vachal)
	Braunsapis trochanterata (Gerstaecker)
	Braunsapis sp.
	Amegilla atrocincta (Lepeletier)
	Amegilla acraensis (fabricius)
	Ceratina (Ctenoceratina)
	Ceratina sp.
	Xylocopa inconstans (Smith)
	Apis mellifera (L.)

While these have generally been considered too weedy to be treated as forest reserves, and of little or no agricultural value, they often have a rich and diverse flora of outstanding botanical interest. Two have been protected in the region. About 10 kilometres away in one direction is ol'Donyo Sabuk, a massive inselberg managed by Kenya Wildlife Services. The lower slopes of the hill are dominated by *Acacia* bushland and thicket. The upper forest is a remnant of a once-common montane forest type dominated by African Olive (*Olea*), Podo (*Podocarpus*), Fig trees (*Ficus*) and Croton. About 10 kilometres in another direction is the Mutomo Hill Plant Sanctuary, gazetteted as a plant sanctuary in the 1950s by the National Museum of Kenya. Interestingly, Mutomo was identified as an important botanical area by the well-known Swiss botanist Peter Bally, and was the first plant, as opposed to wildlife sanctuary established in Africa. While it is unlikely that pollinators visiting the coffee and watermelon that we observed in the region came directly from these reserves, their presence in this largely agricultural landscape may be providing sources of populations of pollinators to establish in agricultural fields (even if they will often be exterminated due to soil disturbance or use of pesticides).

Even more interesting to on-farm biodiversity, however, is the previous practice, almost non-existant in Kenya today, to grow coffee under shade trees. Historically, two indigenous species were used in Kenya for shade-grown coffee: Erthrynia (the famous "Flame Trees of Thika" and Croton. Both of these species are highly attractive to pollinators, as well as to birds and other taxa. The Coffee Research Foundation of Kenya is interested in re-introducing research on shade-grown coffee, which may have sustainability benefits that sun coffee cannot provide. Including a pollination component in such comparative research would be a valuable addition.

Coffea arabica, the most common coffee species in this region, has flowers in groups of 2-20 in the axils of the leaves. The stigma is receptive when a flower opens at dawn, and flowers are usually pollinated within two hours after opening. Flowers wither within 48 hours after opening if pollinated, but persist for much longer if not visited by insects.

Coffee flowers were visited by primarily by honey bees, flies, and other bees, with butterflies, wasps and beetles making up an insignificant contribution (Figure 25). The average number of flowers visited by each of these groups, per 10-minute observations period is given in Figure 26.

TABLE 16. INSECTS BESIDES BEES VISITING COFFEE INCLUDED:

Order	Family	Sub-family	Genus	Species
Coleoptera	Bruchidae	Amblycerinae	*Spermophogus*	*sp*
Diptera	Syrphidae	Milesiinae	*Eristaliaus*	*quinqualineatus*
Diptera	Syrphidae	Syrphinae	*Allograpta*	*Nasuta*
Diptera	Syrphidae	Syrphinae	*Betasyrphus*	*sp.*
Diptera	Syrphidae	Milesiinae	*Phytomia*	*incisa*
Diptera	Syrphidae	Milesiinae	*Eristalinus*	*sp.*
Diptera	Muscidae	Phaoninae	*Atherigona*	*sp.*
Diptera	Muscidae	Muscinae	*Orthellia*	*sp.*
Diptera	Conopidae	-	-	-
Diptera	Calliphoridae	Chrysomyinae	*Chrysomyia*	*sp.*
Diptera	Calliphoridae	Rhiniinae	*Stomorhina*	*rugosa*
Diptera	Calliphoridae	Rhiniinae	*Stegosoma*	*sp.*
Diptera	Calliphoridae	Rhiniinae	*Isomyia*	*sp.*
Diptera	Calliphoridae	Rhiniinae	*Rhinia*	*apicalis*
Diptera	Tipulidae	-	-	-
Diptera	Lauxaniidae	Lauxaniinae	*Lauxania*	*sp.*
Diptera	Lauxaniidae	-	*Pahcycerina*	*sp.*
Diptera	Agromizidae	-	-	-
Diptera	Sciaridae	-	*Apeimocrengris*	*sp.*
Hemiptera	Pyrrhocoridae	-	*Dycercus*	*sp.*
Hymenoptera	Formicidae	Formicinae	*Polyrhachis*	*sp.*
Lepidoptera	Heliodinidae	-	*Eretmocera*	*sp.*
Lepidoptera	Sphingidae	-	*Cephonodes*	*sp.*
Lepidoptera	Pieridae	-	*Catopsilia*	*florella*
Lepidoptera	Papilionidae	-	*Papilio*	*demodocus*
Lepidoptera	Lycaenidae	-	*Leptptes*	*pirithous*
Lepidoptera	Lycaenidae	-	*Cupidesthes*	*arescopa*
Lepidoptera	Nymphalidae	-	*Hypolimnus*	*misippus*

Although ants rapidly scurried over flowers and did visit a considerable number of flowers per ten minute period, they were infrequent, and did not appear to approaching the flowers in ways that ensure proper pollination. Thus, honey bees, flies and other bees were observed as the most effective pollinators (Figures 22, and 26).

Particularly numerous, among the non-*Apis* bee, were *Lasioglossum* (Dialictus sp.) and the two *Braunsapis* species, *Braunsapis fascialis* and *Braunsapis rolini*.

It is interesting to see how pollinators cover the flowering resources as coffee trees enter their peak flowering period. When flowers are less abundant, at the beginning of the flowering season, a typical number of flowers per meter square might be 100 flowers. Over any ten-minute period, an average of twenty may be visited, thus 20%. During peak flowering, of around 3000 flowers per meter square, the total number of flowers visited rises to 40, but the percentage coverage falls dramatically to 1%. It is likely that the pollination community cannot saturate the flowering resources, at peak flowering times- at least in these farms where there is no deliberate effort to enhance pollinator presence by keeping hives of honeybees.

To determine the effectiveness of a single pollinator visit on coffee, which can self-pollinate, forty-six coffee flowers were bagged so that no visitation could occur, and the bags removed to allow a single visit of one honeybee to one flower. (Figure 23). The stigma of this flower was then excised, prepared on a slide and examined under a microscope to count pollen deposited. An equal number of open-pollinated flowers, experiencing unlimited pollination visits, and a small number of control flowers, bagged so as to experience no animal pollinator visits (except possibly ants which might have been able to manoeuvre into the net bags) were examined in the same way. Open pollinated flowers had about twice as many pollen grains deposited on stigmas, as opposed to those flowers experiencing no visits or only one visit.

The importance of insect visitation is apparent, but needs to definitively determine pollinator effectiveness, (as opposed to the rapid assessment conducted here) it is necessary to follow berry development from pollination through to actual yield. Another interesting research question, posed by Dr. David Roubik on the basis of his work on coffee pollination in Costa Rica, is whether pollination may not only contribute to yield, but also to quality. He suggests (D. Roubik, pers. Comm..) that flowers able to widely out-cross (by being visited by far-flying pollinators) may have improved coffee flavour. As coffee production and research is turning increasingly to questions of quality (and the premium prices paid for quality), this is also an important research question for the future, to be answered through a longer-term study that follows pollination through to harvest.

Coffee pollination in its center of origin- Eastern Africa- is a neglected subject that can contribute substantially to coffee yields and possibly quality. Even without managing pollinators, we found that farmers in this agricultural area were still benefiting from pollinators that nest in adjacent wild habitat. Yet this wild habitat is being cleared rapidly as farmers seek to expand their agricultural area. If coffee quality might be enhanced by having more pollinators, the farmers' (erroneous) perceived reduction in yield from not clearing bee-nesting habitat on farm might be made up in actual increases in both yield and quality. Since the coffee tree builds up to peaks of mass flowering, means of conserving pollinators on-farm could have value in assuring that the pollinator community can build up to meet peak flowering periods.

Around the world coffee is principally self and bee pollinated (Roubik 2002 and Klein et. al. 2003.) and Kenya is no exception. Honey bees are the principal pollinators, and much technology exists to manage honey bees. Of the other bees there are soil nesting and above ground nesting bees. These will both occur in natural areas, and certain practices can increase their numbers, like leaving dry wood in place and clearing parts of the ground.

Summary and Conclusions

Most countries wishing to start a pollinator conservation program will be faced with the challenge of assessing the role of pollinators, and knowledge on these roles, in their country. Working out the complete pollination biology of a specific crop is multi-year study, but if pollinators are indeed being lost as agricultural development proceeds, most countries and regions will have neither the time nor resources to study each crop in depth.

As a contribution to the International Pollinator Initiative, the Food and Agriculture Organization of the United Nations invited national partners in Ghana, Kenya and South Africa to undertake a rapid assessment of pollination systems important to crop production in each respective country. Within the scope of time and resources, it was possible to identify and rank the important pollinators for a range of crops, and to identify threats and barriers to pollinator conservation in the different agroecosystems.

Farmers' knowledge of pollination in both Kenya and Ghana was found to be widely variable, from farmers who understood the role of pollination in seed set, to farmers who believe that bees are harmful and need to be killed. Extension agents in Ghana has somewhat better knowledge of pollination services, but did not seem to be actively passing this on to farmers. Researchers and civil society organisations tended to focus on beekeeping as a source of sustainable livelihoods, and were not directly concerned with the conservation of pollination services. The published literature on pollination of crops important in Africa is not small, but few of the studies have been carried out in an African context.

Methodologies are presented here that are easily replicable for a rapid assessment of the important pollinators visiting pollinator-dependent crops. It should be noted that in a rapid assessment, it is not possible to conclusively determine degree of dependence on pollinators and which pollinators are the most effective; this would require a study carried out over one or more years including following the pollination process through to seed set and fruit yield. Moreoever, as is well known in pollination research, the vagility and high variability of insect abundance means that many controlled observation samples of pollinator visitation will result in "zeros"- no visitors. This vastly increases the number of observations needed to carry out statistically analyzable data. In this rapid assesment, we have focused on characterising a number of crop-pollination systems, rather than developing datasets for a statistically complete assessment of any one system.

Within the limitations of the present assessment, however, the ecology of pollination in up to twelve agroecosystems was characterised. In only one of them, deciduous fruit tree farms in South Africa, were honeybees essentially the only pollinator. In all other farming systems, from Ghana to Kenya, a wide array of wild insects visited flowers and were seen to be effective pollinators. While honeybee visits to watermelon are known to be essential to crop production, in Kenya it was shown that two other bees, nesting in the soil of the field, are more effective pollinators. One does not need to be selected over the other; good management of pollination services in agriculture will promote the complex of beneficial insects, so that if one is impacted by disease or weather, others may provide a buffering effect, ensuring that the services are maintained. Information on managing wild ground-nesting bees in agricultural fields is virtually non-existant, however.

Tree crops often recieve visits from a broadly diverse complex of visitors. In Ghana, the importance of flies visiting Mangoes was evident, yet proscriptions for maintaining fly populations in mango orchards are unknown. Papaya's key pollinator, in observations in Kenya, were long-distance flying hawkmoths, whose needs and pollination services are spread across mulitple agro and wild ecosystems. Flies and bees were both important to Avocado pollination in Kenya, although neither are appreciated adequately or managed. Nut crops such as cashew also have a diverse range of pollinators, including several larger bees (honeybees, carpenter bees and leafcutter bees) with good potential as visitors that could be encouraged through pollinator-friendly practices.

Palm crops, such as oil palm and coconut, attract a wide array of small insects, some of which may not directly pollinate, but serve to disturb male flowers sufficiently so that the pollen becomes more easily wind-borne and is carried to female flowers. This highlights the diverse nature of pollination services: what is needed is quite specific to each system, but the role may be carried out by a diverse group of pollinators.

Groundnuts have traditionally thought to be self-pollinated, but in this assessment as well as in some other observations in Africa, the flowers attract insects, and the potential for yield increase in this highly important African crop through pollinator management remains unexplored.

Browse pollinators are important, but often overlooked. Most of the important *Acacia* pollinators nest in dead wood, making room for low-tech pollination management in that farmers that depend on this resource should not denude the areas of dead wood. Browse species such as *Indigofera* are shortlived and respond rapidly to changing climatic conditions through establishment by seed, making their depedence on pollinators very important.

Coffee producers do not seem to be aware that pollination can increase yields, and are removing habitat on farm for wild bee populations. The potential for coffee quality to be increased through management of pollination is gaining considerable public attention, from studies in Costa Rica and Indonesia. Yet in East Africa, in the center of origin of the domesticated coffee crop, there is no appreciation of the role of pollinators, and habitat on-farm is rapidly being degraded. The reintroduction of shade-tree coffee to the region, now being discussed amongst regional research networks, may provide an opporunity to reverse such degradation.

With respect to the taxonomic impediment, it should be noted that many crop and browse pollinator species could only be identified to genera. This severely limits our ability to assess whether they are shared amongst several crops, or specific to individual crops

This rapid assessment has served to bring to the attention of those involved, that pollinator biodiversity conservation in agriculture and in natural ecosystems clearly cannot be separated. An ecosystem approach in pollinator biodiversity conservation must consider a surrounding milieu of well preserved, natural areas, and patches of wild habitat on-farm, to be an integral part of an agro-ecosystem.

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Picture Credits

Front Cover;	Top, Hawkmoth, Dino Martins; Bottom: Cattle in Forest, Matthew Herren
Page 15:	Interview bouquet, Barbara Gemmill-Herren
Page 18:	Peach trees in South Africa, Geoff Tribe
Page 24:	Male flowers, Watermelon, Hannah Nadel
Page 26:	Infloresence and immature fruits of mangoes, Wanja Kinuthia
Page 28:	Male flower of Papaya, Female flower of Papaya, and Herse convolvuli, Dino Martins
Page 33:	Cashew flowers and young fruit, Peter Kwapong
Page 35:	Female Coconut Flowers, Peter Kwapong
Page 37:	Groundnut in flower with flower beetle feeding on petals, Peter Kwapong
Page 39:	Female inflorescence, Oil Palm and Male inflorescence, Oil Palm, Peter Kwapong
Page 41:	Acacia flowers, Dino Martins
Page 47:	Indigofera blossoms and Stingless bee nest entry, Barbara Gemmill-Herren
Page 50:	Honeybees on Coffee, Bagged Coffee inflorescences, Coffee plantation and riparian forest, with wild honeybee hives, Barbara Gemmill-Herren
Back Cover:	Papaya flower and cowpea flower and bee, Dino Martins, Riparian area in coffee plantation, Barbara Herren

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