Insect Pollination of Crops in Brazil

A Guide for Farmers, Gardeners, Politicians and Conservationists

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Prof Dr Alexandra-Maria Klein
Prof Dr Breno M. Freitas
Dr Isac G.A. Bomfim
Dr Virginie Boreux
Dr Felix Fornoff
Dr Mikail O. Oliveira

"I have been an acerola grower for 13 years now. Right here in my plantation I see a lot of bees, they pollinate the plants, and if I have more bees to pollinate I think it will make it even better for the plants and yield because there are a lot of plants to pollinate. I've been working for a long time and I've seen a lot of bees, but I need to know which ones work for acerola and how I can promote their presence here. This pollination guide will be of much help."

Manoel Costa dos Santos
Acerola grower in Sítio Boa Vista dos Valentim, Maranguape, Brazil

"The book 'Insect Pollination of Crops in Brazil' has as main authors current protagonists in research on pollination globally, and presents as its main focus the situation of agricultural pollination in Brazil. This book also represents an important achievement, a partnership between various sectors of society, public and private, that enabled its production, seeking to facilitate horizontal knowledge about bees and their importance for agricultural crops, for the development of Brazil and food security."

Vera Lúcia Imperatriz Fonseca

Senior Professor at the University of Sao Paulo, Brazil

"This guide is an excellent resource for crop pollination researchers, students and agronomists interested in the finer details of crop pollination. This is a one-stop-shop that compiles information regarding pollination requirements, different varieties and flower visitor identity all in one place to optimize pollination in orchards and fields."

Romina Rader

Senior Lecturer in Community Ecology at the University of New England, Australia

"This book is a wonderful resource for Brazilian growers and agronomists working with pollinator-dependent crops, and for beekeepers wishing to promote the value of their stock for pollination services. Here you can easily find the pollination requirements of a crop, understand its floral biology and assess the relative importance of wild and managed pollinators."

Lynn Dicks

Professor at the University of Cambridge, United Kingdom

"The guide is an excellent tool not only for significant improvements in Brazilian agricultural production but also for students to have a holistic view of the pollinating processes, with integrated and very well illustrated information about plant species grown in Brazil, rich details about the biology and ecology of pollinating bees, as well as guidelines for maintaining healthier crops. It certainly improves our interest and understanding of such important insects as bees! "

Maiara Gonçalves

Visiting scholar at the University of Freiburg, Germany

The stingless bee *Frieseomelitta longipes* on a female açaí palm flower

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Foreword

Farmers, gardeners and agronomists have detailed knowledge on how to maximise high quality crop production, especially in the context of external inputs including fertilization and pest management. However, detailed information on pollination is mainly available in the international scientific literature and often not accessible for local farmers or any person interested in growing crops while conserving bee diversity in Brazil.

Pollination is the first step in the reproduction of flowering plants. It is the transfer of pollen from the anthers (male reproduction organ) to the stigma (female reproduction organ) of flowers and therefore essential to develop seeds and to set fruits. Some staple food crops produce yield without insects or other animals and use wind for pollen transfer (e.g. rice, maize and other cereals). Other crops produce fruits or other plant organs we consume without pollination (e.g. banana or cassava). Nevertheless, the majority of crops depend to certain degrees on the transfer of pollen by animals. Only few of the major cultivated animal-pollinated crops around the globe are pollinated by birds and/or mammals such as durian in South-East Asia. Most other crops rely on insect pollinators..

Insect pollination can be provided by external inputs via the introduction of honeybee colonies or other managed pollinators during the crop blooming periods. Honeybee management for crop production is today established for some crop systems. The most famous example is the management of honeybees for almond production in California. Information how the naturally occurring pollinator species, especially wild bee species, contribute to overall crop production is largely missing, although they are crucial pollinators and can be more important than honeybees. The majority of wild bee species do not live in colonies, are therefore less dominant than honeybees and crop pollination increases when many species (biodiversity) share the pollination job. The diversity of wild bees is linked to the crop cultivation practices in the larger agricultural landscapes, in all places of the world. It is therefore crucial to know for each crop the main pollinator species to be able to promote and protect them in our farming systems or the surrounding landscape.

With our crop pollination guide for farmers, gardeners, agronomists, politicians and conservationists, we aim to transfer the current knowledge on crop pollination of the major crop species grown in Brazil. The overarching aims are to provide scientific knowledge of the dependency of a crop on insect pollination and to provide a list of relevant pollinator species for each crop. In detail, we show for each crop the growing regions in Brazil. We provide the pollination requirements, which we define as the plant-mating system and the pollinators visiting the flowers. We also show common examples of the crops cultivated in Brazil. Our flower drawings show flower morphologies. Flowers and pollinators have co-evolved and therefore flower morphology is an important indicator for which pollinators can potentially access the nectar and pollen resources and most importantly which pollinators represent the fitting trait combination to successfully pollinate a flower. Besides providing a list of pollinator species for each crop listed in the scientific primary literature, we display information of pollinator groups in the second part of our crop pollination guide. This information provides the ecological knowledge to enhance the main pollinator groups on farmland, in farms, gardens and the wider landscape.

The idea of this crop pollination guide was developed at the University of Freiburg in collaboration with the Bayer Bee Care Centre of Bayer Crop Science in Germany.

Alexandra-M. Klein and Christian Maus initiated the guide and discussed the idea with Breno M. Freitas from the Departamento de Zootecnia at the Federal University of Ceará in Brazil and later with Martin Urban from Syngenta in Basel, Switzerland and with Juliana Jaramillo Salazar from the Bayer Bee Care Center. Virginie Boreux compiled a global crop pollination database at the University of Freiburg. Felix Fornoff of the University of Freiburg and Isac G. A. Bomfim and Mikail O. Oliveira from the Departamento de Zootecnia at the Federal University of Ceará checked the information and added information from additional publications from Brazil where necessary. They worked with Virginie Boreux on the layout and collected the photos. The University of Freiburg drew the flowers with help of a MSc student. Alexandra M. Klein and Breno M. Freitas wrote the remaining text and corrected the guide until final approval by all authors. Syngenta and Bayer Crop Sciences financed Virginie Boreux to extract information for our guide and financed the translation and print offs of this crop pollination guide. To make the guide accessible to farmers but also to students and the wider society, the English version is permanently stored at DOI:10.6094/UNIFR/151200 and the Portuguese version at DOI: 10.6094/UNIFR/151237. Pdfs are also available at the websites: https://www.nature.uni-freiburg.de/publications/Books, https://ppgzootecnia.ufc.br, https://beecare.bayer.com/home and https://abelha.org.br/.

With this guide on insect pollinaton of crops in Brazil, we aim to increase the current knowledge of farmers and the wider society in Brazil. We hope to rise awareness of the importance of bees, show their beauty and fascinating diversity and to conserve and enhance pollinator diversity in crop-producing systems and landscapes.

Sincerely,


Alexandra-M. Klein & Breno M. Freitas

Contacts

Prof. Alexandra-Maria Klein
Nature Conservation and Landscape Ecology
Faculty of Environment and Natural Resources
University of Freiburg
Tennenbacher Str. 4 79106 - Freiburg - Germany
Email: alexandra.klein@nature.uni-freiburg.de
Phone: + 49 761 203 67770

Prof. Breno M. Freitas
Setor de Abelhas
Departamento de Zootecnia
Centro de Ciências Agrárias
Universidade Federal do Ceará
CEP 60.356-970, Fortaleza - CE, Brazil
Email: freitas@ufc.br
Phone: + 55 85 3366 9220

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Strawberry (*Fragaria × annanassa*) field


The stingless bee *Tetragonisca angustula* collecting pollen of a strawberry flower

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Introduction

Worldwide, most plants produce a fruit or a seed only after successful pollination. Pollination, the process of pollen transfer within or between fertile flowers depends on the plant species under consideration and is most commonly achieved through wind or insects. In about 75% of our global food crops pollination by insects (rarely by birds and mammals) can benefit crop production (Klein et al. 2007) and pollinators are important for optimal reproduction of the majority of wild plants in almost all places of the world (Ollerton et al. 2011). The world annual value of pollinators is estimated between US$ 235-577 billons (IPBES 2016), while in Brazil it is estimated US$ 42-43 billion (Giannini et al. 2015, BPBES 2019). Although many different insect species act as pollinators for specific plants, both managed and wild bees are the main contributors to crop pollination. The managed Western honeybee *Apis mellifera* is often favoured by farmers, as their high number of individuals per colony and long flight and foraging distances lead to potential pollination of large numbers of flowers and spacious crop areas that can be covered by managed pollination. They also provide honey, an important income source for many people including farmers worldwide, and are therefore important domestic animals. High levels of colony losses in some regions of the world over the past decades have increased concerns that scarcity of honeybees might negatively affect food production. While honeybees are the main managed pollinator, wild insects, mainly wild bees have been shown to contribute to the pollination of many crops (Garibaldi et al. 2013, Kleijn et al. 2015). While some crops, for example cocoa, are only pollinated by wild insects (Frimpong et al. 2009), wild bees may always provide some "insurance" to crop production, for example when honeybee colonies are weak or weather conditions are unfavourable for honeybee flight (Winfree et al. 2007, Brittain et al. 2013, Ellis et al. 2017). Pollination by wild bees is also shown to lead to better fruit quality compared to the pollination by honeybees (Klatt et al. 2014, Brittain et al. 2014, MacInnis & Forrest 2019). As of today, wild bee populations of Brazil have not been evaluated, but for some countries, especially in central Europe, insect abundance including pollinating species are discussed to be in severe decline (Potts et al. 2010 & 2016, Hallmann et al. 2018, IPBES 2019, Habel et al. 2019).

Wild bees include feral honeybees (*Apis mellifera*) but usually refer to all bee species excluding *Apis mellifera*. The ecology of wild bees is highly diverse. Some are specialized on a specific plant species; some are highly generalistic visiting a broad range of different flowers or even alternative food resources like fruits. Some species build their nests in dead wood, some in hollow sticks, some mine their nests into the ground, some create it with collected plant materials and others are cuckoo bees parasitizing other bee species (Westrich 1989, Michener 2000). Most species are solitary, where one female creates its own nests and cares for its own offspring, but depending on the species a variety of semisocial to highly eusocial behaviours exist (Michener 2000). Most bees collect nectar to cover their energy demands and collect pollen as the protein source to feed their offspring. The body size determines the flight distance between foraging and nesting areas; small bee species travel only up to 200m, while large bees cover distances of few kilometres (Zurbuchen et al. 2010). Hence, the wild bee ecology requires a nesting site and a foraging ground with flower resources within a limited area. While it is important to maintain suitable flowering plant species, including flowers of many crop species for wild bee species, protection of the breeding and nesting sites and structures is crucial for wild bee reproduction and sustainable populations.

In crop production areas, many different factors can reduce wild bee diversity (number of species and number of individuals). Strong effects can be expected if flowers or nesting sites are limited. Flowers might be reduced by intensive land-use practices, including transformation to non-natural habitat, removal of wild plants or contamination of nectar and pollen. Application of certain pesticides, especially insecticides but also fungicides can also directly harm bees (IPBES 2019), especially when the application is not done in compliance with the safety measures stipulated on the product label. The conversion of non-crop habitat, potentially suitable for nesting wild bees, like the removal of dead wood, turning over of soils, and conversion to urban sealed areas can reduce or eliminate pollinator populations (Klein et al. 2018, Kleijn et al. 2018). For producers of crops that depend on insect pollination it is crucial to maintain a reliable pollinator community which should ideally constitute of as many species as possible, as each additional species increases the reliability of crop pollination even with variable seasonality and weather conditions (Brittain et al. 2013, Ellis et al. 2017). Without the knowledge of the ecology of wild bees, no directed conservation measures can be applied.

Flowers are as variable in morphology and phenology as are their pollinators. The knowledge on which pollinators are important for which flower is crucial for a management towards optimal pollination, including wild pollinators. Therefore, extensive information on the plant-mating system and the pollination system (which animal groups or species are visiting and pollinating the crop flowers) are needed for the assessment of factors potentially affecting pollinators and pollination.

This crop pollination guide of Brazil is presenting the following information:

i) the main crop species grown in Brazil and their pollination requirements

ii) the main pollinating insect groups and species found in Brazil

iii) the management practices that can be used to protect and enhance pollinator populations.

What is "pollination"?

Pollination is the transfer of pollen grains from the male parts (anthers) of a flower to the female parts (stigmas) of a flower, leading to the fertilisation of the ovule or ovules of that flower (Fig 1). When compatible and viable pollen grains touch the stigma, they germinate on the stigma and grow a pollen tube down through the style into the ovary. There, the pollen tube ends and transfers the male genome. This leads to the fertilisation of the ovules containing the female genome. Pollen grains can be deposited on the stigma through biotic (insects, birds, mammals, etc.) or abiotic (wind, water, gravity) agents and pollen tube germination depends on the plant-mating system.

What is a "plant-mating system"?

The plant-mating system describes how a plant reproduces, from pollination to successful fertilisation of the ovule. In most crop species, pollination is required to set fruits and seeds, although in some cases asexual reproduction occurs. Some plants can produce seedless fruits without the transfer of pollen (parthenocarpy e.g. in banana or some pear or cucumber varieties). Other plants can produce fruits with seeds without the transfer of pollen (agamospermy e.g. in some apple varieties). Crops with these two asexual mating systems can however still benefit from the transfer of pollen (Delaplane et al. 2013). For instance production in parthenocarpic cucumber varieties, such as Hokushin, Yoshinari and Soudai, increases up to 40% (for Yoshinari) when bees are visiting flowers (Nicodemo et al. 2013).

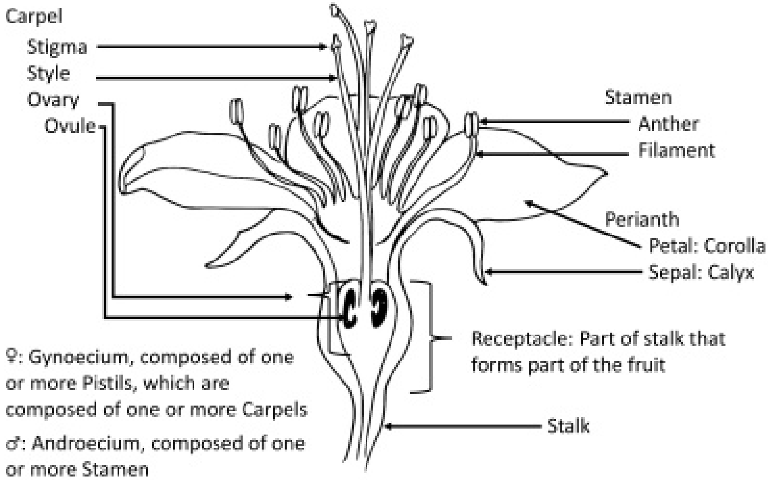

Figure 1: Diagram of a flower showing the different parts involved in pollination and fertilisation of the flower.

All other mating forms reproduce only by successful pollination. Some flowers produce with their own pollen (autogamy, see Fig. 2a) but when pollinators have to transfer the pollen within the flower, the plant is called a self-pollinating species. When the pollen within the flower is transferred without pollinators, the plant is called an auto-pollinating species. Some plants need pollen of another flower of the same plant individual for successful pollination (geitonogamy, Fig. 2b). Geitonogamy is also a form of self pollination. Other crops need the pollen of a flower of a different plant individual (xenogamy, Fig. 2c), which is known as cross pollination. Many plants have a mixed-mating system and can either reproduce with pollen of the same or of other plant individuals, although pollen of different plant individuals often increases fruit and seed production (Delaplane et al. 2000).

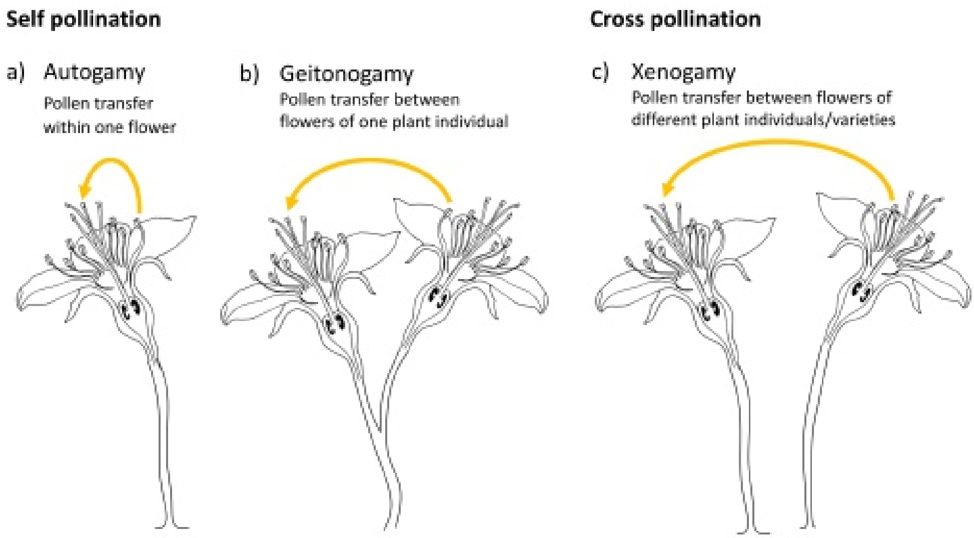

Figure 2: Main plant-mating systems and their mechanisms. a) autogamy, b) geitonogamy, c) xenogamy

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The mating system usually differs between crop varieties. Some produce mainly or strictly with autogamy whereas others produce mainly or strictly with xenogamy. For some crops such as apple, cherry and pear, the compatible pollen has to come from a different variety. For example, xenogamy happens when pollen from a particular variety (e.g. Fuji) fertilises the ovules of a flower from another compatible variety (e.g. Gala). Similarly, autogamy happens in apple when pollen of one variety (e.g. Fuji) is fertilising the ovules of the same variety (in that case, Fuji). For apple, varieties are mostly self incompatible and require pollen from an apple tree of a different variety. Each variety is compatible with a subset of other varieties, e.g. Gala is compatible with Fuji and Eva with Princesa. Unfortunately, up to date information of the mating system is hardly available at the variety level for most Brazilian crops. We therefore provide the most common mating system for a crop if no detailed information of different varieties are available.

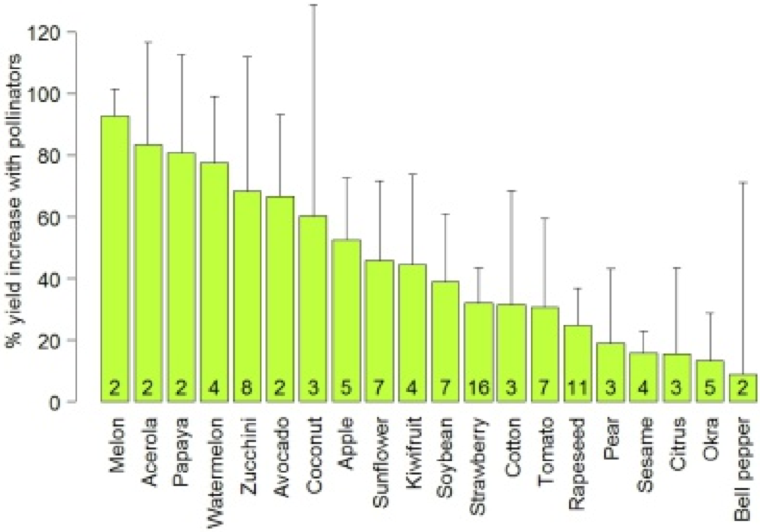

Figure 3: Yield increase (mean and standard error) through presence of pollinators compared to pollinator exclusion (only wind and self pollination). Yield measures were averaged per variety, crop and study and can include values of e.g. seed number, fruit weight and fruit set. The analysis is based on all publications evaluating yield changes published before 2018, including studies outside of Brazil. The number of studies analysed is given within the bars.

When a plant can partly produce with pollen of the same plant (self pollination) the plant is also termed as partially self fertile or partly self-pollinated. Examples of partially self-fertile species include coffee and cucumber. Coffee (*Coffea arabica*) does not require cross pollination (xenogamy) to set fruits, but its production can be increased when bees, likely transporting pollen from different coffee plants, are visiting flowers (Klein et al. 2013). Another example was given above with an increased cucumber production when bees cross-pollinated primarily partheocarpic cucumber varieties (Nicodemo et al. 2013). Therefore, it is usually impossible to assign a crop to only one mating system. In our guide, we indicate the mating systems described in the scientific literature.

Level of dependence on pollinators

The level of pollinator dependency presents the probability of how many flowers turn into fruits when an optimal number of pollinators were available or when pollen was experimentally transferred via hand-cross pollination. The pollinator dependency is given in four categories (essential, high, modest, little) following the mean percent fruit set calculated from the scientific literature according to Klein et al. (2007). Some examples are shown in Fig. 3 which summarizes the results of yield measures obtained from many studies on the comparison of flowers with pollinator exclosure to flowers with insect pollinators present.

Main pollinator groups

There is a substantial diversity of pollinators across the globe. Even though mammals, such as bats or squirrels, pollinate some crop species (e.g. agave, *Agave* spp.; pitaya, *Hylocereus* spp.; *Mucuna macrocarpa*), most crops across the globe are pollinated by insects. Among insect pollinators, honeybees, stingless bees, wild bees and flies (especially hoverflies) are the main and most common pollinators. All crops presented in this guide are pollinated by insects.

In Brazil, and for the crop species presented in this guide, bees were by far the most commonly observed pollinators. However, this is not always the case. For example, certain beetle species are the best pollinators of oil palm (*Elaeis guineensis*) and certain midges pollinate cocoa (*Theobroma cacao*). For this guide, we used a database of scientific literature to compile lists of pollinator identities and extract information on the species-specific pollination success (Table 1 and 2, see methods for information on the database).

Table 1: List of the 20 most common pollinator species visiting crop flowers in Brazil. Occurrence represents the number of scientific papers in which a pollinator species was observed visiting crop flowers.

Species	Occurrence
Apis mellifera	49
Trigona spinipes	24
Xylocopa frontalis	13
Bombus morio	11
Exomalopsis analis	11
Eulaema nigrita	10
Xylocopa grisescens	9
Centris tarsata	9
Centris flavifrons	8
Centris aenea	8
Xylocopa cearensis	6
Paratrigona lineata	6
Trigona fuscipennis	6
Centris fuscata	6
Oxaea flavescens	5
Tetragonisca angustula	5
Eulaema cingulata	5
Bombus atratus	5
Melipona quadrifasciata	5
Centris sponsa	4

Table 2: List of the 20 most common bee genera visiting crop flowers in Brazil. Occurrence represents the number of scientific papers in which a bee genus was observed visiting crop flowers

Genus	Occurrence
Centris	75
Xylocopa	54
Apis	52
Trigona	51
Bombus	30
Exomalopsis	30
Eulaema	25
Epicharis	24
Augochloropsis	21
Augochlora	20
Melipona	19
Plebeia	11
Frieseomelitta	10
Pseudaugochlora	10
Trigonisca	10
Lasioglossum	9
Oxaea	8
Paratrigona	8
Partamona	8
Ceratina	7

Honeybees

Managed Western honeybee

(*Apis mellifera*, Linnaeus, 1758)


Honeybee (*Apis mellifera*) on an avocado flower

The Western honeybee is a highly eusocial species native to Europe, Africa and the Middle East. It is now present in all continents, except Antarctica. Due to its generalistic feeding behaviour, large colonies usually comprising 40,000 - 60,000 bee workers but sometimes reaching up to 80,000, its ease of breeding and managing in manufactured hives and its adaptability to different environment, the Western honeybee is the bee species most commonly managed for pollination of agricultural crops. In Brazil, the use of honeybees as managed pollinators is still limited and done in large scales mainly in melon and watermelon fields in the northeastern region and apple and peach orchards in the southern part of the country. However, the introduction of honeybee colonies for pollination of canola and soybean has increased recently after researchers demonstrated considerable yield gains (Rosa et al. 2011, Milfont et al. 2013).

Africanized honeybee

The term 'Africanized honeybee' refers to the polyhybrid bee produced from the accidental and uncontrolled crossing of four European sub-species of *Apis mellifera* (*A. m. mellifera*, *A.m. ligustica*, *A m. carnica*, *A. m. caucasica*) introduced to Brazil in the 1800´s and an African race (*A. m. scutellata*) brought to the country in 1956. However, genetic studies suggest that this miscegenation was not even throughout the country and while in southern parts it is evident, colonies in other regions are genetically close to *A.m. scutellata* leading some scientists to simply use the term Africanized honeybees to refer to African honeybees in the Americas. These bees have been naturalized, are now dominant in the whole country and are usually kept for the production of honey, pollen, propolis, wax and also for crop pollination.


Honeybee (*Apis mellifera*) on a pear flower

Across the world, 11 species of honeybees (*Apis* spp.) exist. In this guide we summarize literature that does not always discriminate between Africanized honeybees and Western honeybees, both subspecies of *Apis mellifera*. To account for this uncertainty and differentiate any kind of subspecies originating from *Apis mellifera* from other honeybees we use the term “honeybee”.

Social wild bees

Stingless bees (*Scaptotrigona* sp.) on rambutam flowers

Many different social and eusocial wild bees occur and act as important pollinators. These include bumblebees (*Bombus* spp.) as well as stingless bees (e.g. *Melipona* spp.). In Brazil, their contribution to crop pollination comes from feral colonies nesting around cultivated areas. Only recently, a few stingless bee species are being studied aiming for their use as managed pollinators in crops. However, the small colony size and slow build up of the population associated with slow colony reproduction makes it difficult to keep them for crop pollination at a larger scale. Unlike other bumblebee species around the world, Brazilian bumblebees are extremely defensive and attack fiercely everyone approaching their nests. Due to this highly defensive behaviour, their colonies are usually exterminated by farmers when naturally occurring on their farms. Scientists and bee breeders avoid using them in experiments to prove their value as crop pollinators. The import of foreign bumblebee species is forbidden by law in Brazil.

Solitary wild bees

This group covers a substantial array of wild bees, which are very different in habits and morphology. It ranges from the large carpenter bees (Apidae) to the small sweat bees (Halictidae). Despite having solitary nesting behaviour, many species are gregarious and nest side by side building up large natural populations becoming important pollinators for wild and cultivated plants. Some species of solitary bees are already bred in captivity and used for pollination purpose in some countries around the world. In Brazil, despite the existence of a great number of solitary bee species proven important pollinators of crops, there is no systematic breeding and use of any species as pollinator. The predominantly tropical climate of Brazil allows bees to be active all-year round. and the high diversity of solitary bees seems promising for the systematic management of some species as crop pollinators.

Solitary bee (*Augochlora* sp.) on a tomato flower

Wasps

Solitary wasp on a cotton flower

Wasps comprise a group of insects closely related to bees and like bees, there are solitary and social species. However, unlike bee larvae that feed on nectar and pollen, wasp larvae are carnivorous and feed on spiders, caterpillars or other insects hunted by the adult wasps. Despite this feeding behaviour of their brood, adult wasps usually feed on nectar and pollen, hence visiting and sometimes pollinating flowers. Some plants are even strongly dependent on wasp pollination. For example in the well-known pollination coevolution involving fig wasps (Agonidae) and wild figs (*Ficus* spp.), fruits are only produced after wasp pollination. In general wasps are extremely important to agriculture because, although there are no crops in this guide entirely dependent on wasps for pollination, they contribute to the pollination of a variety of crops such as raspberries, and also prey on important agricultural pests such as caterpillars, aphids and cicadas. Solitary wasps contributing to pollination and pest control can be supported by the same practices listed for solitary bees in the chapter "Managing pollinators".

Flies

Biting midge on a cocoa flower

Flies belong to an ancient insect group characterized by having only one pair of fully developed wings. So far 160,000 species were named but a multitude of undescribed species is expected to exist worldwide (Borkent et al. 2018). Many fly species are valuable pollinators of flowers especially of the families Bombylidae, Tachinidae and Syrphidae. Flies show a variety of forms and sizes and include for example short- to long-tongued species. They pollinate a variety of wild and cultivated plants and can be important for increasing yield in crops such as mango (*Mangifera indica*) and are essential for cocoa (*Theobroma cacao*) yield and seed production of some vegetables.

Beetles

Curculionid beetles on oil plam flowers

Beetles are the most species-rich insect order worldwide, but in the context of crop production commonly seen as crop pests rather than pollinators. Indeed, many of them are relevant pests but others are important pollinators of plants in the tropics, particularly in Brazil. Besides many crop species where they can contribute to increase yield, some crops of local, national and worldwide importance such as custard apple (*Annona reticulata*), soursop (*Annona muricata*), and palm oil (*Elaeis guineensis*) are totally dependent on beetle species to set and produce fruits.

Methodology

Crop selection

Major crops of Brazil for which pollinators are important were selected for this guide, based on the authors' expert knowledge. With this, our aim was to cover most of locally and generally important crops of Brazil. However, Brazil is home to many more known crop species and others are still not described or valuated for cultivation. Even though, this guide is not complete it covers a wide range of the major crops in Brazil. For completeness and as an outlook, we composed a list of all generally known crop species of Brazil, including our estimate of pollinator attractiveness and insect pollination dependency at page 105-107.

Data on crops and pollinators

Data concerning crops grown in Brazil, their plant-mating system, varieties, pollinators as well as information concerning fruit set and seed set were extracted from a database on crop pollination collected between 2012-2018 at the University of Freiburg, Germany. When data were not available for Brazil, data from other countries in South America were used from the database. If no such data were available in the database, the crops were excluded from the guide. Bee pollinators observed in South America but not Brazil were checked against Moure's database (http://moure.cria.org.br/credits) to find if their range includes Brazil as well. If so, they were included in the pollinator list of the crop, if not they were removed. Species of midges were similarly checked using the publication of Santarém and Felippe-Bauer (2017) and species of ants the publication of Ulysséa et al. (2011). The database at University of Freiburg was built using scientific publications on crop pollination. Publications were identified and gathered using the search engines ISI Web of Knowledge (http://apps.webofknowledge.com/) and Google Scholar (http://scholar.google.com/). For each crop, the following search strings were used on both websites: i) scientific name of the species AND pollin*, ii) scientific name of the species AND pollen, iii) scientific name of the species AND nectar iv) common name of the species AND pollin*, v) common name of the species AND pollen, vi) common name of the species AND nectar. Data on crops (varieties studied, breeding system, flowering and harvesting time), pollinators (name, forage target, abundance) and their impact on production were extracted from the scientific publications.

Disclaimer crop attractiveness score

Any classification of attractiveness has been made based on expert judgement and using the best scientific knowledge available. This classification does not represent an absolute truth because attractiveness is depending on many variable factors such as variety, manners of cultivation, environment, etc. For these reasons, the authors cannot assume any liability for decisions made using this classification.

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Explanations

Attractiveness score: To give an indication of the attractiveness of each crop, we used a scale ranging from 1 to 5, as follows:

1 – Crop has a **low or no** attractiveness for animal pollinators ....

2 – Crop has a **low to medium** attractiveness for animal pollinators ....

3 – Crop has a **medium** attractiveness for animal pollinators ....

4 – Crop has **medium to high** attractiveness for animal pollinators ....

5 – Crop is **highly** attractive to animal pollinators ....

NA – degree of attractiveness is unknown

Cultivation: The type of cultivation (open fields, shaded, agroforests etc.) which might be relevant from the pollinators` perspective.

Distribution map: Distribution maps were drawn based on information available at floradobrasil (http://floradobrasil.jbrj.gov.br/) and completed using the authors' knowledge.

Flower description: Hand drawn lateral cross section of flowers showing reproductive organs based on templates, available copyright free at the repository plantillustrations.org (see http://plantillustrations.org, under creative commons licence). Further information describing the flower morphology and organs is given in the text.

Flowering and harvest periods: If available, flowering times were taken from the data base and checked by Brazilian authors of this guide. Many crops are grown at different times of the year throughout Brazil. Therefore, this information is only a rough approximation and may not be applicable in all regions.

Growing areas: List of Brazilian states (abbreviated, see list of abbreviations) where the crop is grown.

Pollinator dependency: Indicating the dependency of a crop on pollinating insects for optimal fruit and seed production. Based on experiments comparing seed and fruit production with and without animal pollinators the following categories were assigned:

Essential - pollinators are essential for most varieties (production reduction by ≥ 90% without pollinators)

High - high production increase with insect pollinators (40 - <90% reduction without pollinators)

Modest - modest production increase with insect pollinators (10 - <40% reduction without pollinators)

Little - little production increase with insect pollinators (>0 - <10% reduction without pollinators)

Main varieties grown in Brazil: Only the most commonly cultivated and established varieties are listed.

Other information: Information relating to fruit set or seed set. When available taken from Brazilian or other South American papers of the database or any additional information according to the knowledge and experiences of the authors.

Plant-mating system: Description of the distribution of mating units in a plant population (see glossary for detailed descriptions).

Pollination requirements: More detailed information on the plant-mating system together with the flower morphology and physiology to better understand the pollination requirements.

References: List of references providing information mostly on the pollinator species but also on additional information of the crop.

Status: Native/cultivated (i.e. introduced)/naturalised.

Table of pollinators: List of flower-visiting insect species found in the scientific studies of the database. Common names were entered if available; otherwise, the common name of the genus was used. We describe the sociality of the pollinators in terms of "eusocial", "social" or "solitary".

Glossary

Agamospermy: Flower sets fruits and seeds without the transfer of pollen/pollination

Agroforest: Area used for the production of one to several types of understory crop and one to several crop trees and/or bushes

Androdioecious: Some plant individuals with male and female reproduction organs on the same plant individual and other individuals with male flowers

Androecious: Plant individuals produce only male flowers

Andromonoecious: Bisexual and male flowers on the same plant individual

Anemophilous: Wind pollinated

Anther: Head of the stamen producing the pollen

Auto pollination: Form of self pollination in which the flower transfers pollen from its anthers to its stigma without the aid of a pollinating agent (pollinator, wind, etc.)

Autogamy: Flower sets fruits and seeds with pollen of it's own stamens

Bract: A modified leave usually associated to flowers, it serves to protect the flower and sometimes to attract pollinators

Buzz pollination: Usually flowers with porous anthers require bees to buzz (sonicate) the flowers to loosen the pollen. This behaviour called "buzz pollination" is specific to certain species of bees, such as *Bombus* spp. The insect vibrates its flight muscles at high frequency when visiting a flower, releasing the pollen enclosed in the anthers. Some flowers, e.g. tomato flowers, are pollinated by buzz pollination

Carpel: The female organ of a flower consisting of four major parts: stigma, style, ovary, ovules. When several carpels in a flower are connate, the whole structure is termed pistil

Cauliflorous: A plant with the flowers at the woody stem or trunk

Cleistogamous: Pollination occurring in unopened flowers. Virtually all plants that produce cleistogamous flowers also produce flowers that open (chasmogamous flowers)

Cross pollination: The transfer of pollen from the male reproductive organ (anther) of one plant individual to the female reproductive organ (stigma) of another plant individual. This mechanism requires abiotic (e.g. wind, water) or biotic (animals) agents and is termed xenogamy

Dichogamous (dichogamy): Bisexual flower, but female function and male function are separated in time

Dioecious: Individual flowers are either male or female, but only one sex per plant individual occurs. Therefore, the presence of male and female plants is required to set fruits and seeds

Distylous (distyly): Species with two morphologically different flower types that are self-incompatible, but cross-compatible

Entomophilous: Plant requires insect pollination for optimal fruit set

Eusocial: see Social/Sociality

Field: Area used for the production of fruits from forbs, herbs or grasses

Filament: Stalk attached to the flower and holding the anther

Flower visitor: An animal that touches a flower. Even though not all flower visitors contribute to pollination, many flower visitors carry pollen at least accidentally and often act as pollinators. Although we can often not distinguish between pollinators and flower visitors from the scientific data we refer to all flower visitors as potential pollinators as the chance that a flower-visiting species act as a pollinator is high

Foraging resources (for pollinators): Many insect pollinators (mainly bees) usually use two types of food resources, pollen and nectar, which they collect from flowers

Geitonogamy: Flower sets fruits and seeds after pollination with pollen of another flower of the same plant individual. This needs a pollination agent such as a biotic pollinator or wind

Gynodioecious: Some plant individuals with male and female reproductive organs on the same individual and other individuals with female flowers only

Gynoecious: Plant individuals produce only female flowers

Half-inferior ovary: Ovary embedded or surrounded by the receptacle. This ovary position is also termed subinferior or half superior

Hermaphrodite: Flowers have both male and female reproductive organs

Home garden: Area used for the production of a variety of crops used for subsistence

Inferior ovary: Ovary lies below the attachment of other floral parts

Inflorescence: Cluster of flowers arranged on a stem that is composed of a main branch or an arrangement of branches (compound inflorescences)

Mellitophilous: Plant requires bee pollination for optimal fruit set

Mixed-mating system: A combination of any of the different main mating systems: agamospermy, parthenocarpy, autogamy, geitonogamy and xenogamy. We refer to a mixed-mating system when cross and self pollination occurs. Otherwise, we specify the mix of the mating system for specific crops

Monoecious: Individual flowers are either male or female but on the same plant individual

Nesting resources (for pollinators): Insect pollinators, in particular bees, nest in a

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variety of mediums, including sandy soil (e.g. ground-nesting bees such as *Centris* spp.) and hollow twigs and branches (e.g. cavity-nesting bees such as *Tetrapedia* spp.)

Orchard: Area used for the production of fruits of trees and bushes

Ovary: The swollen location at the base of the pistil in a flower that houses the ovules containing the female gamete

Ovules: The flower eggs located inside the ovary. Successfully pollinated they will grow into seeds

Panicle: Inflorescence with many branches

Parthenocarpy: Flower sets seedless fruits without the transfer of pollen/pollination

Pedicel: Stem that attaches a single flower to the inflorescence

Perianth: Petals and sepals together when it is possible to distinguish between the two. Otherwise, it is termed perigonium

Perigonium: The non-reproductive part of the flower, and structure that forms an envelope surrounding the sexual organs

Petals: Modified leaves surrounding the reproductive parts in a flower. Petals are often brightly coloured to attract pollinators. Taking all petals in a flower together is termed corolla

Pistil: The pistils of a flower are considered to be composed of carpels. The gynoecium may consist of one or more pistils

Pistillode: Sterile usually rudimentary (reduced) pistil

Plantation: Area used for the production of usually one type of cash crop (plant (-part) sold to the market)

Plant-mating system: The plant-mating system describes the distribution of mating units in a plant population. In flowering plants it refers to self pollination (self fertilization), to cross pollination (outcrossing) and to reproduction without mating. In this guide we refer to the following forms of mating systems: agamospermy, parthenocarpy, autogamy (self pollination and auto pollination), geitonogamy, xenogamy and a mix of these mating systems termed mixed-mating system. We explain these seven forms of mating systems separately

Pollinizer: Plant (sometimes a specific cultivar) that provides abundant, compatible, and viable pollen

Pollination: The transfer of pollen grains from the male reproductive organs (anthers) to the female reproductive organs (stigmas)

Pollinator: An insect (or another animal), which interacts with a flower, usually by landing or climbing on it, and contributes to pollination. The animal transports pollen on its body, which touches the female reproductive organ of the flower (stigma). If this happens, the flower-visiting insect is usually classified as a pollinator. In only few studies on flower visiting insects, further analyses are carried out in how far flower visitors are indeed pollinating, for example by looking at the pollen tube growth in the style, or checking the fruit set of the visited flower after several days

Polygamous: Hermaphrodite, male and female flowers on the same individual

Protandrous, protandry: Anthers mature before the stigmas

Protogynous hermaphroditism: A flower changes from female to hermaphrodite

Protogynous, protogyny: Stigmas mature before the anthers

Radial symmetrical flowers: Flowers can be divided into three or more identical sectors, which are related to each other by rotation around the flower centre

Receptacle: The part of a flower stalk where the parts of the flower are attached

Self-compatible plants: A species which can set fruits or seeds by self-pollinating its stigmas with its own pollen. Self-compatible plants do not require cross pollination for successful production, but can benefit from it

Self-incompatible plants: A species that can set fruits only when pollen comes from different plant individuals from the same species. Self-incompatible plants require wind or animal pollination, and do not set fruits by self pollination. Self incompatibility is usually associated to cross pollination

Self pollination: The transfer of pollen from the male reproductive organ (anther) of one flower to the female reproductive organ (stigma) in the same flower (autogamy) or to the stigmas of another flower of the same plant (geitonogamy). This can be done passively (auto pollination) or via biotic or abiotic pollinating agents

Sepals: Modified leaves usually surrounding the petals. They are usually green and function to protect the reproductive flower organs in a bud. Taking all petals in a flower together is termed calyx

Social/sociality: While most bee species are solitary, honeybees, bumblebees and stingless bees live in complex societies with clear tasks for queens, workers and males. These three bee groups are also termed as eusocial, which is the most evolved form of sociality expressing features like the simultaneous existence of different generations in one colony and the existence of non-reproductive castes which are doing brood care. Social organisation can also vary within some bee species. For example, some species of sweat bees (Halictidae) express solitary or social behaviour in different environments or at different live stages. Another type of social system can emerge when several females of the same generation join to initiate a new colony. Such behaviours in forming social organisations are termed semi-social

Solitary: Most bee species live solitary, meaning that each female builds its own nest. There is no division of labor and no different castes. A female bee searches for a nesting place and starts to build brood cells for example with leaves in a reed internode, collect pollen as larval food and lay an egg in each brood cell. After closing a nest the female leaves their progeny to their own devices

Stamen: Male organ of the flower consisting of the filament and anther. It is also termed androecium

Staminode: Sterile usually rudimentary stamen

Stigma and style: The female part of a flower. The stigma is the top part of the style, where deposited pollen grains can grow into pollen tubes when they are compatible with the flower

Stigma: The sticky end of the style responsible to catch pollen and the place in the flower where pollen germination starts

Style: A thin tube-like structure holding the stigma. It is connected with the ovary at its base

Superior ovary: Ovary is attached to the receptacle above the attachment of other flower parts

Tepals: Modified leaves surrounding the reproductive parts of a flower and comprises petals and sepals. The term is only used when petals and sepals cannot be easily separated. Taking all tepals in a flower together is termed perigonium

Wind pollination: Reproduction with airborne pollen transferred by wind

Xenogamy: Flower sets fruits and seeds with pollen of another flower of another plant individual. This needs a pollination agent such as a pollinator or wind

Zygomorph: Flower symmetry is bilateral

States of Brazil

State	**abbreviation**
Acre	AC
Alagoas	AL
Amapá	AP
Amazonas	AM
Bahia	BA
Ceará	CE
Distrito Federal	DF
Espírito Santo	ES
Goiás	GO
Maranhão	MA
Mato Grosso	MT
Mato Grosso do Sul	MS
Minas Gerais	MG
Pará	PA
Paraíba	PB
Paraná	PR
Pernambuco	PE
Piauí	PI
Rio de Janeiro	RJ
Rio Grande do Norte	RN
Rio Grande do Sul	RS
Rondônia	RO
Roraima	RR
Santa Catarina	SC
São Paulo	SP
Sergipe	SE
Tocantins	TO

Crop pollination

Açaí palm/Açaí *Euterpe oleracea* Mart.

Arecacea

Status: Native

Growing areas: AP, PA, TO, MA, GO

Cultivation: Semi shade in light woodlands/ agroforestry systems or no shade in open plantations

Attractiveness score: 5

Pollinator dependency: High

Plant-mating system: Mixed-mating system (xenogamy and geitonogamy)

Pollination requirements

Highly dependent on insect pollination, especially beetles, honeybees and stingless bees. Wind contributes little to pollination.

Flowering and harvest periods

Flowering: January to May

Harvest: September to December

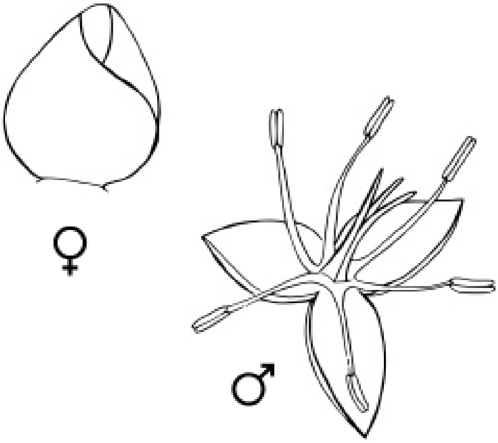
Main varieties grown in Brazil

Açaí-roxo, Açaí chumbinho, Açaí tinga, Açaí-açu, Açaí-branco, Açaí-espada, Açaí-sangue-de-boi

Some varieties have a dark skin and purple juice while others have a dark-green skin and greenish juice

Other information

Açaí palm is pollinated by a diverse range of insects, including curculionid beetles, generalist bees, beetles, flies and wasps. It was shown that pollinator diversity increases fruit set. The exclosure of pollinators visiting only male or female flowers, for example ants, can increase pollination and fruit set. An extensive list of pollinators is given in Campbell et al. (2018).



Flower description

Monoecious palm species with female and male flowers on large inflorescences of the same plant individual. Asynchrony of male and female flowers can occur. Flower symmetry is radially symmetrical. ♀ flowers are purple to light brown with sepals and petals broadly triangular, with a trilocular ovary with three stigmas. ♂ flowers are purplish with sepals triangular to ovate and petals ovate purple to purplered. Male flowers bear six free stamens arranged on a short receptacle.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bees	*Melipona fasciculata*	Eusocial
Stingless bees	*Melipona flavolineata*	Eusocial
Stingless bees	*Frieseomelitta longipes*	Eusocial
Solitary bee	*Anthophila* sp.	Solitary
Other bees	Apidae	Eusocial/Social/Solitary
Flies	Diptera	Solitary
Wasps	Apocrita	Eusocial/Social/Solitary
Beetles	Coleoptera	Solitary
Ants	Formicidae	Eusocial

Further information: A recent study of Campbell et al. (2018) demonstrates that (1) the palm is pollinated by more than 100 different types of insects, (2) fruit production is 25% higher in areas with high diversity of pollinators; (3) extensively used mixed forest stands support insect diversity pollinating açaí palm and (4) bees pollinating açaí palm were more dependent on the mixed forest stands than other pollinating insects. It is therefore important to conserve extensively used mixed forest stands adjacent to the açaí palm production areas or to manage açaí palm in diverse agroforestry systems with low pesticide inputs.

The stingless bee *Frieseomelitta longipes* on a female açaí palm flower

References

Campbell (2018); Lamarão (2018); Nascimento (2008); Oliveira do (2000); Venturieri (2008)

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Acerola/Acerola *Malpighia emarginata* DC.

Malpighiaceae

Status: Cultivated, originates from the northern Neotropics

Growing areas: AM, PA, BA, GO, ES, MG, RJ, SP, PR, PE, PB, PI, CE

Cultivation: Shrubs in open plantations

Attractiveness score: 3

Pollinator dependency: High

Plant-mating system: Self pollination (geitonogamy) and cross pollination (xenogamy) occur

Pollination requirements

The flower can potentially be pollinated by an array of insect flower visitors, but only oil-collecting bee species, especially those of the genus *Centris*, find it very attractive and visit the flowers regularly.

Flowering and harvest periods

Flowering: Year round

Harvest: Year round

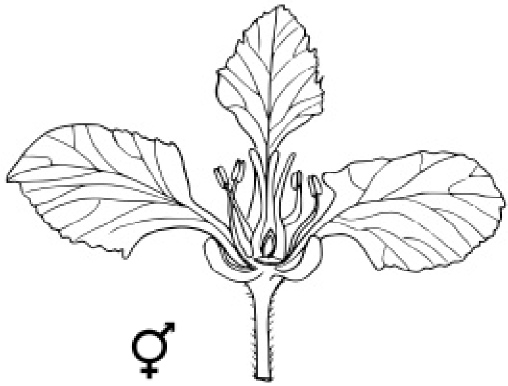
Main varieties grown in Brazil

C. F. Rehnborg, F. Haley Red Jumbo, Hawaiian Queen, J. H. Beaumont, Manoa Sweet, Maunawili, Tropical Ruby

Other information

Acerola pollination is highly dependent on oil-collecting bees. Despite high levels of natural pollination, only an average of 30 % flowers set fruits. As many oil-collecting bee species prefer to use pre-existing holes in dead trees and other species nest in the soil. The presence of dead trees and soil with open vegetation in the vicinity of acerola cultivation is beneficial.

Bees visiting acerola also visit many other wild plants during acerola bloom. Hence, the presence of these plants may benefit acerola pollination. A study from the savannah of Central Brazil highlighted the potential to cultivate acerola in savannah areas when natural ecosystems that provide nesting and flowering resources, promoting bee diversity, are available.



Flower description

Flowers are hermaphrodite and radially symmetrical with five pale to deep pink fringed petals. Each inflorescence with three to five flowers. ♀ organ with three styles emerging from a fused ovary. ♂ organ with ten stamen, all with fertile anthers.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Trigona spinipes*	Eusocial
Oil-collecting bee	*Centris varia*	Solitary
Oil-collecting bee	*Centris aenea*	Solitary
Oil-collecting bee	*Centris tarsata*	Solitary
Oil-collecting bee	*Centris analis*	Solitary
Oil-collecting bee	*Centris flavifrons*	Solitary
Oil-collecting bee	*Centris nitens*	Solitary
Oil-collecting bee	*Centris spilopoda*	Solitary
Oil-collecting bee	*Centris fuscata*	Solitary
Oil-collecting bee	*Centris sponsa*	Solitary
Oil-collecting bee	*Centris vittata*	Solitary
Oil-collecting bee	*Centris bicolor*	Solitary
Oil-collecting bee	*Centris inermis*	Solitary
Oil-collecting bee	*Centris scopipes*	Solitary
Oil-collecting bee	*Centris longimana*	Solitary
Oil-collecting bee	*Centris mocsaryi*	Solitary
Oil-collecting bee	*Centris denudans*	Solitary
Oil-collecting bee	*Centris trigonoides*	Solitary
Oil-collecting bee	*Epicharis affinis*	Solitary
Oil-collecting bee	*Epicharis albofasciata*	Solitary
Oil-collecting bee	*Epicharis analis*	Solitary
Oil-collecting bee	*Epicharis bicolor*	Solitary
Oil-collecting bee	*Epicharis cockerelli*	Solitary
Carpenter bee	*Xylocopa cearensis*	Solitary

References

Calgaro (2012); Freitas et al. (1999); Guedes et al. (2011); Magalhães & Freitas (2013); Oliveira et al. (2013); Vilhena et al. (2012)

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Anatto/Urucum *Bixa orellana* L.

Status: Native (pan tropical)

Growing areas: All states of Brazil

Cultivation: Open plantations

Attractiveness score: 4

Pollinator dependency: High

Plant-mating system: Primarily cross pollination (xenogamy), small degree of self pollination (autogamy, geitonogamy)

Pollination requirements

Annatto is mainly buzz pollinated by carpenter bees, bumblebees and stingless bees. Self pollination leads to low fruit set, confirming that cross pollination (xenogamy) is the main reproductive strategy.

Flowering and harvest periods

Flowering: year round

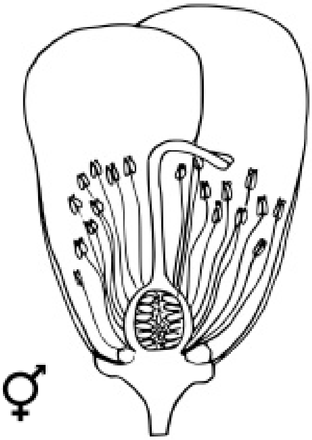
Harvest: year round

Main varieties grown in Brazil

Bico-de-Pato, BR-36, BR-37, Peruana Pará, Peruana Paulista, Piave Vermelha

Other information

Large bees such as carpenter bees, orchid bees and bumblebees but also small bees such as stingless bees (especially *Melipona* sp.) perform buzz pollination, vibrating the anthers and are therefore excellent pollinators, increasing fruit set. Honeybees, soft-wing flower beetles and ants are frequent flower visitors but contribute only little to pollination as they do not buzz pollinate and rarely touch the elongated stigma. Fruits produced by self pollination were shown to be lighter with less seeds than fruits originating from cross pollination. We assume that a combination of different pollinator species able to buzz pollinate and to transfer large amounts of pollen is the best strategy to pollinate annatto.



Flower description

Annato trees have hermaphrodite flowers and flowers are radially symmetrical with four to five sepals and four to seven petals that often tend to curve up. Flowers are coloured pinkish, whitish or purplish. ♀ flower organ composed of one long pistil with bristly one-celled, superior ovary and the style thickened upwards with a short, two-lobed stigma. ♂ flower organ with numerous violet stamens and anthers.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Bumblebee	*Bombus morio*	Social
Bumblebee	*Bombus* sp.	Social
Orchid bee	*Centris* sp.	Solitary
Orchid bee	*Euglossa* sp.	Solitary
Orchid bee	*Eulaema nigrita*	Solitary
Stingless bee	*Melipona subnitida*	Eusocial
Stingless bee	*Schwarziana quadripunctata*	Eusocial
Stingless bee	*Tetragonisca angustula*	Eusocial
Stingless bee	*Tetragonisca* sp.	Eusocial
Stingless bee	*Trigona spinipes*	Eusocial
Carpenter bee	*Xylocopa frontalis*	Solitary
Carpenter bee	*Xylocopa* sp.	Solitary
Beetle	*Astylus* sp.	Solitary
Ants	Formicidae	Eusocial

The stingless bee *Melipona subnitida* on an anatto flower

References

Caro et al. (2017); Castro (2009); Costa et al. (2008); Fabriet al. (2008); Rocha & Polatto (2017)

Apple/Maçã *Malus domestica* Borkh.

Rosaceae

Status: Cultivated, originates from Central Asia

Growing areas: BA, MG, SP, PR, RS, SC

Cultivation: Open plantations/orchards

Attractiveness score: 4

Pollinator dependency: High

Plant-mating system: Most varieties with primarily cross pollination (xenogamy) but small degree of self pollination (autogamy, geitonogamy) and also parthenocarpy occurs

Pollination requirements

Generally, apple flowers need cross pollen from compatible varieties, acting as pollinizers, to set fruits. Pollen is transferred by insects and not wind because apple pollen is too heavy to become airborne. Flowers provide both nectar and pollen to insect populations and are attractive for many insects, especially bees.

Flowering and harvest periods

Flowering: August to October, both flowering and harvest depend on the variety and state where it is cultivated. Flowering last for 15 days, flowers open for three to five days

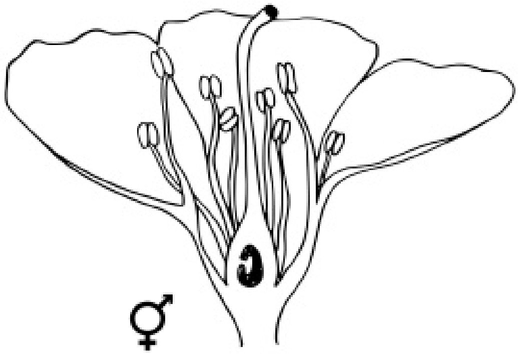
Harvest: December to January

Main varieties grown in Brazil

Anna, Brasil, Catarina, Condessa, Eva, Fuji, Gala, Golden Delicious, Granny Smith

Other information

Apis mellifera is the main pollinator but flowers are also visited by many solitary bee species and bumblebees. Pollinator effectiveness of different bee species varies among apple varieties due to variation in flower morphology. For example, *Apis mellifera* often collect nectar from the side of the stigma of large flowers reducing the transfer of pollen. Small insects also often fail to touch the stigma to transfer pollen. Optimal pollination increases seed number to ten seeds and fruit calcium content, important for storage quality. Orchards with few pollinators risk a low quality harvest.



Flower description

Apple are deciduous trees with hermaphrodite flowers and flowers are radially symmetrical with five petals and sepals. Petal colour changes from white to deep pink with successful pollination. The central flower of the inflorescence is termed king flower and opens first and can develop a larger fruit. ♀ organ composed of one carpel with five stigmas with styles united at the base. Each of the five ovaries usually carries two seeds. ♂ organ with about 20 stamens in three whorls (10 + 5 + 5) with yellow anthers.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Schwarziana quadripunctata*	Eusocial
Bumblebees	*Bombus* sp.	Social
Solitary bees	*Augochloropsis* sp.	Solitary
Solitary bees	*Dialictus* sp.	Solitary

Wasp on an apple flower

Honeybee (*Apis mellifera*) on an apple flower

References

Benedek & Nyeki (1997); Blitzer et al. (2016); Boyle & Philogène (1983); DeGrandi-Hoffman et al. (1985); Free (1962); Free (1966a); Free (1966b); Free & Spencer-Booth (1964); Freitas (1995); Goodell & Thomson (1997); Hem & Mattu (2014); Kendall & Solomon (1973); Kuhn & Ambrose (1984); Lewis & Smith (1969); Mayer (1984); Nunes-Silva et al. (2016); Park et al. (2016); Salomé (2014); Schneider et al. (2002); Smith & Lewis (1972); Stern et al. (2001); Storhaug (2014); Torchio (1985); Viana et al. (2015); Vicens & Bosh (2000)

Avocado/Abacate *Persea americana* Mill.

Lauraceae

Status: Naturalized, originates from Mexico

Growing areas: AL, BA, CE, PB, PE, RN, SE, ES, MG, RJ, SP, PR, RS, SC

Cultivation: Mainly in open plantations

Attractiveness score: 4

Pollinator dependency: High

Plant-mating system: Cross pollination (xenogamy) always enhances fruit production. Self pollination is technically not possible as stigmas are not receptive at day times when pollen is released

Pollination requirements

Flowers provide nectar and pollen and are attractive to bees, flies and even bats are sometimes visiting flowers. All varieties have flowers with a protogynous dichogamy pollination mechanism with two flowering types of different varieties: flowers open as female in the morning of the first day and close in late morning or early afternoon. The next day they open as male in the afternoon. Alternatively, they open as female in the afternoon of the first day, close in late afternoon, and reopen as male the next morning.

Flowering and harvest periods

Flowering: year round in the overall country, but few weeks in each region

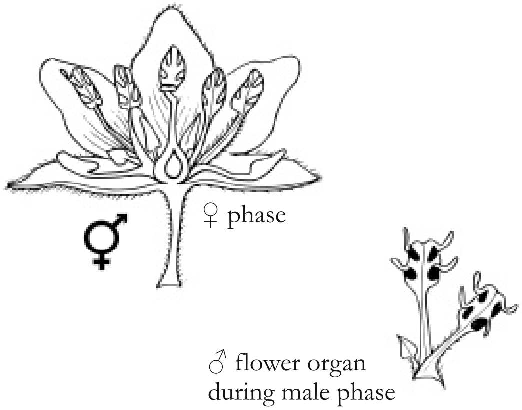
Harvest: year round in the overall country, but few weeks in each region

Main varieties grown in Brazil

Antilhano, Bertanha, Breda, Emor, Fortuna, Fuerte, Geada, Guatemalense, Hass, Herculano, Linda, Margarida, Ouro Verde, Paulista, Pollock, Princesa, Quintal, Simmonds Solano Wagner, Waldin, Westin

Other information

At least two cultivars of different dichogamy variations should be planted less than 100 m apart from each other to ensure optimal pollen transfer and pollination success. Flowers contain nectaries with additional sugary rewards for pollinators.

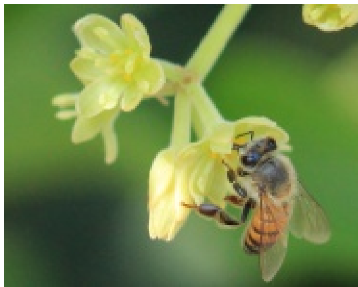


Flower description

Flowers of the perennial tree are protogynous hermaphrodite. Each flower is radially symmetrical and inconspicuous, small (5-10mm) and greenish-yellow with two perianth whorls with six tepals altogether. ♀ flower organ is hairy and consists of one unicarpellate ovary and the stylus carries a slightly lobed stigma ♂ flower organ composed of 12 stamens in four whorls.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Trigona fulviventris*	Eusocial
Bumblebee	*Bombus* sp.	Social
Other bees	*Exomalopsis* sp.	Solitary
Blow fly	*Chrysomya megacephala*	Solitary
Wasp	*Polistes canadensis*	Social



Avocado fruit is a mass flowering crop, producing millions of flowers, most of which are shed without producing fruits. Because of the many flowers, the crop is attractive for social insects and the flower-visiting community is usually dominated by honeybees, which are effective pollinators for avocado plantations.

Table 3: Avocado flower opening sequence for flowering types A and B. For example Hass is a variety of flower type A, Forte a variety of flower type B they can be planted together to ensure optimal cross pollination when honeybees or other bees are available.

Flower type/ Variety	Day 1 Morning	Day 1 Afternoon	Day 2 Morning	Day 2 Afternoon
A	female	closed	closed	male
B	closed	female	male	closed

References

Clark (1923); Davenport (1986); Ish-Am et al. (1998, 1999); Ish-Am & Eisikowitch (1993, 1998); Papademetriou (1976); Perez-Balam et al. (2012); Read et al. (2017); Vithanage (1990)

Brazil nut/Castanha do Brasil *Bertholletia excelsa* Bonpl.

Lecythidaceae

Status: Native

Growing areas: AC, AM, AP, PA, RO, RR, MT

Cultivation: Open plantations

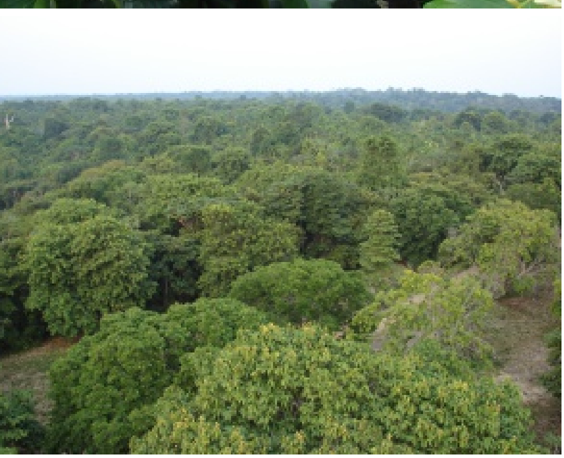
Attractiveness score: 4

Pollinator dependency: Essential

Plant-mating system: Predominantly cross pollination (xenogamy)

Pollination requirements

Where cultivated, brazil nut is a mellitophilous cross-pollinated crop. It is considered self-incompatible, but some fruits result from geitonogamy.



Flowering and harvest periods

Flowering: September to December

Harvest: January to April

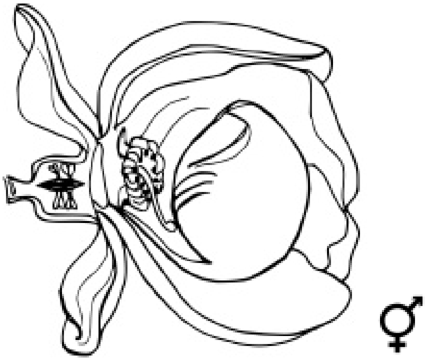
Main varieties grown in Brazil

Abufari, 609, 606

Other information

The brazil nut is a plant species still under the process of cultivation. Most of the nuts are collected from wild trees and much less from planted tree individuals. Only large bees, especially orchid bees, are strong enough to access the flower and pollinate. These bees are usually solitary wild bees nesting in natural habitats, therefore is the proximity to rainforest important to ensure the presence of these pollinators in adequate numbers and diversity of species for sufficient pollination.

Brazil nut is an example showing how important it is to conserve rainforest in Brazil as we are currently not able to manage the large wild bee species pollinating brazil nut flowers. Most of the large bees depend on resources of intact rainforest. In a nutshell “No rainforest, no brazil nut”.



Flower description

Flowers are hermaphrodite and bilaterally symmetrical with a globous appearance and six yellow-cream petals over a thick receptacle. The androecium includes a hood of sterile, nectar producing appendages that cover a ring of fertile stamens beneath. ♀ organ with inferior ovary and short styles. ♂ organ with short and numerous stamens.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Frieseomelitta longipes*	Eusocial
Stingless bee	*Melipona lateralis*	Eusocial
Bumblebee	*Bombus brevivillus*	Social
Bumblebee	*Bombus transversalis*	Social
Oil-collecting bee	*Epicharis conica*	Solitary
Oil-collecting bee	*Epicharis umbraculata*	Solitary
Oil-collecting bee	*Epicharis zonata*	Solitary
Oil-collecting bee	*Centris americana*	Solitary
Oil-collecting bee	*Centris carrikeri*	Solitary
Oil-collecting bee	*Centris ferruginea*	Solitary
Oil-collecting bee	*Centris denudans*	Solitary
Orchid bee	*Eulaema meriana*	Solitary
Orchid bee	*Eulaema mocsaryi*	Solitary
Orchid bee	*Eulaema cingulata*	Solitary
Orchid bee	*Eufrisea purpurata*	Solitary
Orchid bee	*Eufrisea flaviventris*	Solitary
Carpenter bee	*Xylocopa frontalis*	Solitary
Leafcutter bee	*Megachile* sp.	Solitary

The orchid bee *Eulaema meriana* collecting pollen and nectar from a brazil nut flower

References

Cavalcante (2008); Cavalcante et al. (2012); Cavalcante et al. (2018); Maués et al. (2015); Ministério da Agricultura, Pecuária e Abastecimento (2014); Nelson et al. (1985); Prance (1976); Santos & Absy (2010); Santos & Absy (2012)

Brazilian grapetree/Jabuticaba *Plinia cauliflora* (Mart.) Kausel

Status: Native

Growing areas: PR, SC, MG, RJ, ES, BA, PE, SP, PB

Cultivation: Open plantations

Plant-mating system: Mixed-mating system (autogamy, geitonogamy, xenogamy)

Attractiveness score: 3

Pollinator dependency: Little

Myrtaceae

Pollination requirements

It has been reported that solitary trees bear poorly compared to trees planted in groups, which indicates that cross pollination may enhance productivity. Pollinator exclusion experiments showed only slight increases in fruit set of cross-pollinated compared to self-pollinated flowers.

Flowering and harvest periods

Flowering: July to August

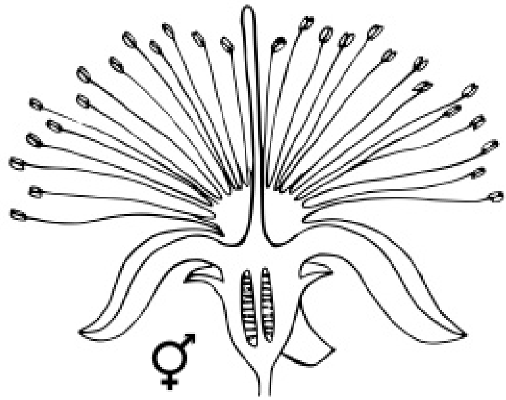
Harvest: September to November

Main varieties grown in Brazil

Branca, Mineira, Paulista, Ponhema, Rajada, Roxa, Rujada, Sabará, São Paulo

Other information

Flowers of the slow-growing evergreen tree are visited mainly by bees, especially honeybees. Other insects such as flies and wasps also visit the flowers. The crop can produce commercially without pollinators, but flowers are visited by many different beneficial insects. Therefore, if applied, spraying of pesticides, especially insecticides, has to be avoided when the crop is in bloom. When the brazilian grapetree is planted in a garden it can be a valuable pollen and nectar source for insects at a certain time. But also gardeners should avoid pesticides at least when the tree is in bloom. As the fruits are consumed by wild birds this crop can promote wildlife in private gardens or public parks.




Flower description

The cauliflorous flowers are hermaphrodite and radially symmetrical with small, white petals. ♀ flower organ consists of a single compound pistil with a single style and stigma. ♂ flower organ consists of numerous stamens.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Tetragonisca angustula*	Eusocial
Stingless bee	*Trigona spinipes*	Eusocial
Other bees	*Chloralictus* sp.	Solitary
Wasps	Apocrita	Solitary/Social
Flies	Diptera	Solitary


A solitary bee on a brazilian grapetree flower

References

Gobato et al. (2018); Gressler et al. (2006); Malerbo et al. (1991); Malerbo-Souza et al. (2004); Morton (1987)

⇧

Canola/Canola *Brassica napus* L.

Status: Cultivated, originates from Europe

Growing areas: RS, PR, MG, SC, MT

Cultivation: Open fields

Attractiveness score: 5

Pollinator dependency: Modest

Plant-mating system: Dependent on the variety mostly self pollination (autogamy, geitonogamy) but cross pollination (xenogamy) can occur

Pollination requirements

Canola is considered a predominantly self-pollinated and self-compatible plant. Pollen transport by insects (mainly bees) or wind can lead to higher seed set, seed quality and yield. Although canola flowers remain open for 12 to 96 hours, the period in which they can be fertilized varies only from 4 to 24 hours.

Flowering and harvest periods

Flowering: July to September

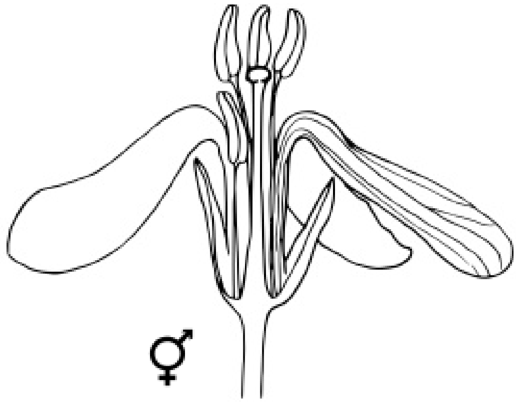
Harvest: August to November

Main varieties grown in Brazil

CTC-4, Hyola 401, Hyola 411, Hyola 420, Hyola 43, Hyola 432, Hyola 433, Hyola 60, Hyola 61, Hyola 76, PFB-2

Other information

Autogamous self pollination through gravity is most likely during the onset of the anthesis, when the stigma is below the interiorly facing anthers and hence pollen falls easily on the stigma. Once the stigma exceeds the anthers self pollination (geitonogamy) and cross pollination through insects and wind is facilitated. The introduction of honeybee colonies to canola plantation can, depending on the canola variety, increase crop yield. Moreover, wild social and solitary bees have been shown to work in a complementary way increasing the pollination rates and productivity of canola seeds. As canola is pollinated by many wild bee species but fields provide no nesting resources, farmers should provide set aside patches with flowering herbs adjacent to and within large fields.



Flower description

Flowers are hermaphrodite and radially symmetrical with four yellow petals alternating with four sepals in the typical crosswise arrangement. ♀ organ with one single carpel and a superior ovary. ♂ organ with two lateral stamens with short filaments and 4 long stamens.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Trigona spinipes*	Eusocial
Stingless bee	*Plebeia emerina*	Eusocial
Stingless bee	*Plebeia droryana*	Eusocial
Stingless bee	*Plebeia nigriceps*	Eusocial
Stingless bee	*Mourella caerulea*	Eusocial
Stingless bee	*Nannotrigona testaceicornis*	Eusocial
Stingless bee	*Scaptotrigona bipunctata*	Eusocial
Stingless bee	*Schwarziana quadripunctata*	Eusocial
Stingless bee	*Tetragonisca fiebrigi*	Eusocial
Bumblebee	*Bombus* sp.	Social
Bumblebee	*Bombus pauloensis*	Social
Carpenter bee	*Xylocopa* sp.	Solitary
Leafcutter bee	*Megachile* sp.	Solitary
Mining bee	*Callonychium petuniae*	Solitary
Small carpenter bees	*Ceratina* sp.	Solitary
Sweat bee	*Lasioglossum phaedrum*	Solitary/Social
Sweat bee	*Thectochlora alaris*	Solitary/Social
Sweat bee	*Dialictus pabulator*	Solitary/Social
Sweat bee	*Dialictus* sp.	Solitary/Social

List continues at p. 120

References

Abrol & Shankar (2012); Adegas & Nogueira Couto (1992); Arthur et al. (2010); Benedek & Prenner (1972); Blochtein et al. (2015); Bommarco et al. (2012); Brunel et al. (1994); Chambó et al. (2014); Chifflet et al. (2011); Eisikowitch (1981); Free & Ferguson (1980, 1983); Free & Nuttall (1968); Hayter & Cresswell (2006); Holzschuh et al. (2011); Hoyle et al. (2007); Jauker et al. (2012); Jenkinson & Glynne Jones (1953); Kamel et al. (2015); Kevan & Eisikowitch (1990); Koltowski (2001a,b & 2002, 2005, 2007); Langridge & Goodman (1982); Marsaro-Jr. (2017); Mesquida et al. (1988); Mesquida & Renard (1979, 1981); Mesquida et al. (1988)

List continues at p. 119

Cashew/Caju *Anacardium occidentale* L.

Status: Native

Growing areas: AC, AM, AP, PA, RR, TO, AL, BA, CE, MA, PB, PE, PI, RN, SE, DF, GO, MS, MT, ES, MG, RJ, SP

Cultivation: Open plantations

Attractiveness score: 4

Pollinator dependency: High

Plant-mating system: Self pollination (geitonogamy) and cross pollination (xenogamy)

Pollination requirements

Insects transporting pollen from the large stamen of either male or hermaphrodite flowers are effective pollinators, whereas wind plays a minor role in cashew pollination. Pollen from hermaphrodite flower staminoids are unfertile or show very low germination and therefore pollination rates.

Flowering and harvest periods

Flowering: June to October

Harvest: August to December

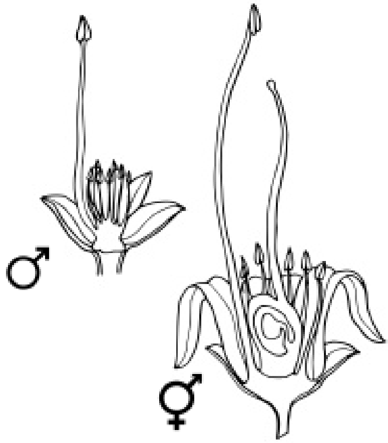
Main varieties grown in Brazil

Dwarf varieties (BRS 189, BRS 226, BRS 253, BRS 265, CCP 06, CCP 09, CCP 1001, CCP 76, Embrapa 50, Embrapa 51), Giant variety (BRS 274)

Other information

Self pollination produces low yield while cross pollination results in high fruit set and harvest. *Apis mellifera* is the most common pollinator in cashew orchards but the presence of wild bees increases yield.

Oil-collecting bees of the genus *Centris* are good pollinators of cashew flowers. However, they only occur in areas where oil-flower plants are present because they need their oil for nest building and cell provisioning. Cashew growers can attract them to their orchards intercropping cashew with an oil-flower species such as acerola (*Malphigia emarginata*) (Freitas & Pereira, 2004).



Flower description

Flowers are male or hermaphrodite and appear radially symmetrical with five backwards bent, white or pinkish petals. Male flowers are more numerous. ♀ organ with a hairless ovoid ovary and a long lateral style. ♂ organ with a corona of stamens surrounding the ovary, which is rudimentary in male flowers. One stamen is exerted and nine are short and inserted.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Trigona spinipes*	Eusocial
Stingless bee	*Plebeia* sp.	Eusocial
Stingless bee	*Melipona subnitida*	Eusocial
Stingless bee	*Scaptotrigona* sp.	Eusocial
Stingless bee	*Trigona* sp.	Eusocial
Bumblebee	*Bombus* sp.	Social
Oil-collecting bee	*Centris analis*	Solitary
Oil-collecting bee	*Centris flavifrons*	Solitary
Oil-collecting bee	*Centris fuscata*	Solitary
Oil-collecting bee	*Centris sponsa*	Solitary
Oil-collecting bee	*Centris tarsata*	Solitary
Cleptoparasitic bee	*Coelioxys* sp.	Solitary
Orchid bee	*Euglossa* sp.	Solitary
Leafcutter bee	*Megachile* sp.	Solitary
Carpenter bee	*Xylocopa grisescens*	Solitary
Carpenter bee	*Xylocopa cearensis*	Solitary
Other bee	*Exomalopsis* sp.	Solitary
Wasp	*Polistes* sp.	Social
Ant	*Camponotus* sp.	Social

Further information: The management of honeybee colonies in cashew plantations during blossom increases flower visits and optimizes fruit and nuts harvest. Additionally cashew provides abundant resources for honeybees allowing income through the harvest of valuable bee products like honey, beeswax and propolis.

References

Bhattacharya (2004); Eradasappa & Mohana (2016); Freitas (2018); Freitas et al. (2002, 2014a,b); Freitas & Paxton (1996, 1998); Freitas & Pereira (2004); Heard et al. (1990); Holanda Neto et al. (2002)

Castor bean/Mamona *Ricinus communis* L.

Euphorbiaceae

Status: Naturalized, originates from Eastern Africa to India

Growing areas: BA, CE, MG, PR, PE, PI, RN, SP

Cultivation: Open fields

Attractiveness score: 2

Pollinator dependency: Modest

Plant-mating system: Cross- and self pollination (mixed-mating system), male flowers are below female flowers hence self pollination (geitonogamy) and cross pollination (xenogamy) occurs, of which the first was shown to increase reproductive success.

Pollination requirements

Castor flowers are cross-pollinated mainly by wind, whereas bees contribute to self pollination. Honeybees promote geitonogamy in two ways: i) by actively transporting pollen from male flowers to female flowers of the same inflorescence when they search for nectar at extrafloral nectaries located at the base of each pedicel; ii) passively by activating the explosive dehiscence of pollen from the anthers during foraging activities. This increases the amount of airborne pollen mostly pollinating the stigmas of female flowers on the same or neighbouring inflorescence.

Flowering and harvest periods

Flowering period: December to July

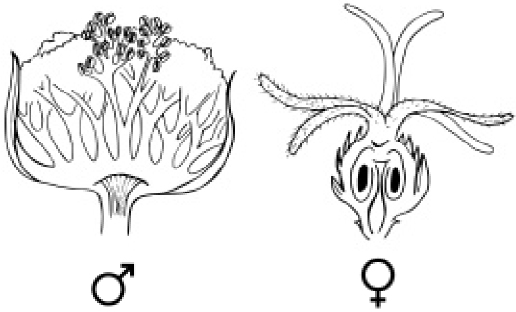
Harvest period: February to Octber

Main varieties grown in Brazil

Al Guarany 2002, BRS 149 Nordestina, BRS 188 Sertaneja (Paraguaçu), BRS Energia, IAC 2028, IAC 226, IAC 80, IAC Guarani

Other information

The introduction of honeybee colonies in castor bean plantations increases crop fruit set per inflorescence and seed oil content.



Flower description

Flowers are monoecious, with radially symmetrical male and female flowers on one plant with three to five sepals. Ovoid male flowers yellowish-green with creamy stamens. ♀ flower with superior ovary covered by soft spines and a short style with three prominent red, deeply two-parted stigmatic branches. ♂ flower with many yellowish stamens, branched and tightly packed together in a perianth. Premature flowers are green and ovoid.

Flower visitors and pollinators

Common name	**Scientific name**	**Sociality**
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Scaptotrigona bipunctata*	Eusocial

Stingless bees (*Scaptotrigona* sp.) on castor bean flowers

Honeybee (*Apis mellifera*) on castor bean flowers

References

Giannini et al. (2015); Rizzardo (2007); Rizzardo et al. (2012)

Citrus, Lime, Orange/Frutas cítricas *Citrus spp.* L.

Rutaceae

Status: Naturalized, originate from Southeast Asia.

Growing areas: BA, DF, GO, MS, MG, SP, PR, RS, SC

Cultivation: Open plantations

Attractiveness score: 4

Pollinator dependency: Little

Plant-mating system:

Citrus is an aggregated group of more than ten species grown in Brazil with many varieties and including all mating systems ranging from agamospermy and parthenocarpy (seedless mandarins) to all forms of self- and cross pollination

Pollination requirements

Many varieties of grapefruit, lemon, lime and oranges are agamosperm or parthenocarpic and do not require pollination to set fruits. However some varieties, especially pomelo and mandarins, require or benefit from entomophilous cross pollination to set fruits or to improve yield, juice content or sweetness. In general citrus plants are attractive to pollinators.

Flowering and harvest periods

Flowering: September to November

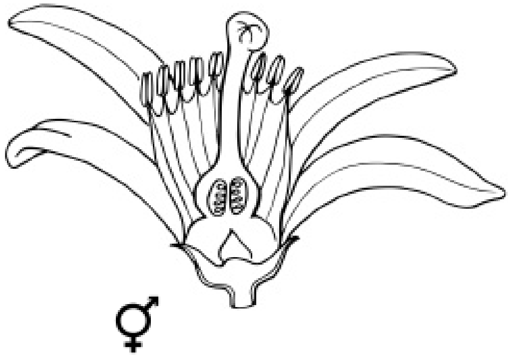
Harvest: February to June

Main varieties grown in Brazil

Oranges: Baianinha (Piralima), Charmute de Brotas, Hamlin, João Nunes, Natal, Pera Rio, Pineapple, Rubi, Seleta, Valência, Valência Americana1, Valência Folha Murcha, Westin. **List continues at p. 119**

Other information

In some orange varieties, like ‘Pera Rio’, fruit set increases when pollinators have access to the flowers and flowers open to pollinators even bear more fruits than hand-cross-pollinated flowers. Pollination also increases seed numbers, depending on how the fruits will be used, this can decrease their market value. In the same variety yield increases up to 30% with honeybee visitation.



Flower description

Flowers are mainly hermaphrodite and radially symmetrical. The five petals are white, thick and leathery. ♀ flower organ consists of a superior ovary, one single cylindrical style and a big, round stigma. ♂ flower organ with numerous stamens with yellow quadrilobate anthers and a short, rudimentary pistil.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Melipona quadrifasciata*	Eusocial
Stingless bee	*Melipona scutellaris*	Eusocial
Stingless bee	*Tetragonisca angustula*	Eusocial
Stingless bee	*Frieseomelitta* sp.	Eusocial
Carpenter bee	*Xylocopa grisescens*	Solitary
Carpenter bee	*Xylocopa suspecta*	Solitary
Small carpenter bee	*Ceratina* sp.	Solitary
Oil-collecting bee	*Centris analis*	Solitary
Oil-collecting bee	*Centris fuscata*	Solitary
Sweat bee	*Augochlora* sp.	Solitary/Social
Masked bee	*Hylaeus* sp.	Solitary
Leafcutter bee	*Megachile* sp.	Solitary

Honeybee (*Apis mellifera*) on a lemon flower

References

Grajales-Conesa et al. (2013); Malerbo-Souza et al. (2004); Ribeiro et al. (2017); Toledo et al. (2013)

Cocoa/Cacau *Theobroma cacao* L.

Malvaceae

Status: Native

Growing areas: AC, AM, AP, PA, RO, BA, MA, RR

Cultivation: Agroforest

Attractiveness score: 4

Pollinator dependency: Essential

Plant-mating system: mostly cross pollination (xenogamy)

Pollination requirements

Most varieties of cocoa are self-incompatible and self pollination produces no fruit set. Naturally, midges (Diptera) are the most important pollinators. Hand-cross pollination produces very high fruit set and fruits can be five times heavier than open-pollinated flowers, which suggests a pollination deficit in cultivation areas.

Flowering and harvest periods

Flowering: October to May

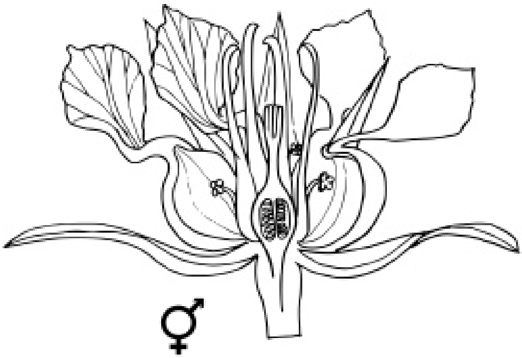
Harvest: April to August

Main varieties grown in Brazil

Criollo, Forastero, Trinitário

Other information

Many insects live on and visit the flowers of cocoa, but most do not contribute to pollination. Usually natural fruit set is only 0,3% (3 in every 1,000 flowers). Small-sized stingless bees were tested as potential cocoa pollinators, but despite the evidence that they visit the flowers their efficiency as pollinators is still to be proven. When hand pollination is considered, it should be avoided to set the maximum number of fruits in a given year because this weakens the tree, which may die or become too weak for a good yield in the following year. The main pollinating insects are midges (Ceratopogonidae, also known as biting midges or gnats) which need moisture to reproduce. Moist microhabitats can be promoted by leaving decaying organic materials in the agroforestry systems. Insect control of nuisance biting midges should be reconsidered as their removal might lead to pollination failure or a low quality harvest.



Flower description

Flowers are hermaphrodite, cauliflorous and radially symmetrical with five triangular, whitish or reddish sepals and five whitish-yellow petals with dark purple bands, fused into a cup-like structure at the base. ♀ organ with superior ovary and a single style terminating in five sticky lobes. ♂ organ with five fertile stamens fused, each with two anthers, alternating with five staminodes. The two whorls together form a tube.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Biting midge	*Forcipomyia nana*	Solitary
Biting midge	*Culicoides fluviatilis*	Solitary
Biting midge	*Forcipomyia jipajapae*	Solitary
Biting midge	*Atrichopogon fusculus*	Solitary
Biting midge	*Culicoides diabolicus*	Solitary
Biting midge	*Culicoides glabellus*	Solitary
Biting midge	*Culicoides hylas*	Solitary
Biting midge	*Culicoides paraensis*	Solitary
Biting midge	*Culicoides pusillus*	Solitary
Biting midge	*Fittkauhelea amazonica*	Solitary
Biting midge	*Forcipomyia argenteola*	Solitary
Biting midge	*Forcipomyia blantoni*	Solitary
Biting midge	*Forcipomyia cinctipes*	Solitary
Biting midge	*Forcipomyia genualis*	Solitary
Biting midge	*Forcipomyia quatei*	Solitary
Biting midge	*Forcipomyia spatulifera*	Solitary
Biting midge	*Forcipomyia squamitibia*	Solitary
Stingless bee	*Tetragonisca angustula*	Eusocial
Stingless bee	*Plebeia* cf. *flavocincta*	Eusocial

Biting midge on a cocoa flower

References

Adjaloo & Oduro (2013); Chumacero de Schawe et al. (2016); Erickson et al. (1988); Frimpong et al. (2009); Groeneveld et al. (2010); Lemos (2014); Lopes et al. (2011); Santarém & Felippe-Bauer (2016); Silva et al. (2011); Soria (1981); Young (1982); Young (1983)

Coconut/Coco *Cocos nucifera* L.

Arecaceae

Status: Naturalized in Brazil. Pan-tropical but likely originated in South Asia and Melanesia

Growing areas: PA, AL, BA, CE, MA, PB, PE, PI, RN, SE, ES, RJ, SP

Cultivation: Mainly in open plantations or single trees in gardens or along streets or in agroforests

Attractiveness score: 4

Pollinator dependency: Modest

Plant-mating system: Mixed-mating system (geitono- and xenogamy)

Pollination requirements

Dioescious flowers are present in the same inflorescence and male flowers mature before female flowers. Wind pollination can facilitate self- and cross pollination. Flowers are also attractive for insects and especially in windless areas bees facilitate self- and cross pollination and this was shown to increase production.

Flowering and harvest periods

Flowering: year round

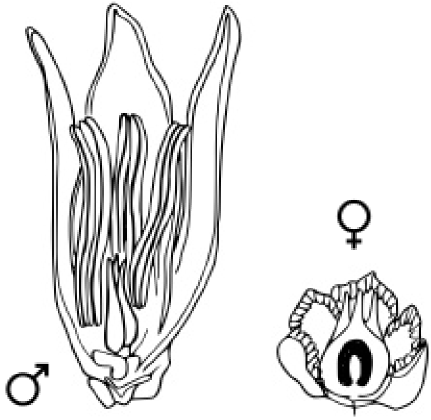
Harvest: year round

Main varieties grown in Brazil

Giant cultivars: Gigante-da-Costa-Oeste, Gigante-da-Malásia, Gigante-da-Praia-do-Forte, Gigante-de-Renell, Gigante-do-Oeste-Africano; dwarf cultivars: Anão-amarelo da Malásia, Anão-amarelo de Gramame, Anão-verde-de-Jequi, Anão-verde-do-Brasil, Anão-vermelho da Malásia, Anão-vermelho de Camarões, Anão-vermelho de Gramame; hybrid cultivars: PB 111, PB 121, PB 131, PB 141

Other information

Male flowers are highly attractive as pollen source and female flowers as nectar source for honeybees. Hand- cross pollination increases fruit set over self pollination and insect-mediated pollination increases yield over wind pollination. Wasps visit the female flowers for nectar but carry little amounts of pollen. Studies from outside of Brazil reported weevils as important pollinators.



Flower description

Coconut trees are monoecious with radially symmetrical female and male flowers occurring in the same inflorescences. Flowers are small, light yellow and the perianth usually consists of two whorls of three rudimentary petals and sepals. Male flowers are more numerous than female flowers. ♀ flower with three pistils. ♂ flower with six stamens consisting of two whorls with three stamens each.

Flower visitors and pollinators

Common name	**Scientific name**	**Sociality**
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Melipona quadrifasciata*	Eusocial
Stingless bee	*Oxytrigona tataira*	Eusocial
Stingless bees	*Trigona* sp.	Eusocial
Sweat bee	*Augochlora* sp.	Solitary/Social

Honeybee (*Apis mellifera*) on coconut flowers

Stingless bee on coconut flowers

References

Benassi et al. (2013); Conceição et al. (2004); De Castro M.S. (2002); Free et al. (1975); Hedström (1986); Melendez-Ramırez et al. (2004); Regi & Josephrajkumar (2013)

Coffee/Café *Coffea arabica* L.

Rubiaceae

Status: Cultivated, originates from highlands of Ethiopia

Growing areas: AC, AL, BA, CE, DF, ES, GO, MG, MS, PB, PE, PR, RJ, RO, RS, SC, SE, SP

Cultivation: Open plantations, agroforests

Attractiveness score: 4

Pollinator dependency: Modest

Plant-mating system: Self pollination (autogamy, geitonogamy) and cross pollination (xenogamy)

Pollination requirements

Coffea arabica is self-compatible and flowers can auto pollinate under certain circumstances. Wind pollination occurs, but self- and cross pollination mediated by bees significantly increases fruit set.

Flowering and harvest periods

Flower: August to October

Harvest: April to May

Main varieties grown in Brazil

Acaiá, Acauã, Catuaí, Mundo Novo

Other information

Coffea arabica is the coffee species most cultivated in Brazil (70% of crops). Another coffee species, *C. canephora*, known as Robusta, is also cultivated in the country (30%). This species is self-incompatible and depends on cross pollination by bees and wind.

For a long time it was thought that, only Robusta coffee needs bees for optimal pollination. Then several studies showed that common varieties of Arabica coffee in different places of the world, including South America produces more fruits when bees are visiting the coffee flowers. It was also shown that social bees contribute effectively to coffee production but many of the wild social bees depend on resources of intact rainforest. Therefore, coffee production can be promoted by the vicinity of intact rainforest. D.W Roubik mentioned in a personal communication that the taste of coffee can even be better when bees are pollinating the coffee flowers.

⚥

Flower description

Flowers are hermaphrodite and radially symmetrical with five sepals and five white petals forming a star-shaped corolla tube with a sweet scent. ♀ organ with inferior ovaries and two united unilocular carpels. The slender style terminates in short, two-parted stigmas. ♂ organ with five stamens inserted in the corolla tube and anthers on long, slender filaments.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Bumblebee	*Bombus brevivillus*	Social
Bumblebee	*Bombus morio*	Social
Stingless bee	*Cephalotrigona capitata*	Eusocial
Stingless bee	*Geotrigona subterranea*	Eusocial
Stingless bee	*Nannotrigona testaceicornis*	Eusocial
Stingless bee	*Tetragonisca angustula*	Eusocial
Stingless bee	*Trigona amalthea*	Eusocial
Stingless bee	*Trigona spinipes*	Eusocial
Oil-collecting bee	*Centris aenea*	Solitary
Oil-collecting bee	*Centris decolorata*	Solitary
Oil-collecting bee	*Centris flavifrons*	Solitary
Oil-collecting bee	*Centris tarsata*	Solitary
Small carpenter bee	*Ceratina chloris*	Solitary
Other bee	*Exomalopsis iridipennis*	Solitary
Carpenter bee	*Xylocopa grisescens*	Solitary
Stingless bee	*Paratrigona* sp.	Eusocial
Stingless bee	*Plebeia* sp.	Eusocial
Stingless bee	*Trigona* sp.	Eusocial
Sweat bee	*Augochlora* sp.	Solitary/Social
Sweat bee	*Augochloropsis* sp.	Solitary/Social
Oil-collecting bee	*Centris* sp.	Solitary
Small carpenter bee	*Ceratina* sp.	Solitary
Carpenter bee	*Xylocopa* sp.	Solitary

References

Badano & Vergara (2011); Brokaw (2013); Hipolito et al. (2018); Hutchinson (2012); Klein et al. (2003 a,b); Mesquita et al. (2016); Philpott et al. (2006); Roubik (2002); Tarno et al. (2018); Veddeler et al. (2008); Vergara & Badano (2009)

Common bean/Feijão *Phaseolus vulgaris* L.

Fabaceae

Status: Cultivated, originated from Mesoamerica

Growing areas: All states of Brazil

Cultivation: Open plantations and gardens

Attractiveness score: 4

Pollinator dependency: Little

Plant-mating system: Most varieties with primarily self pollination (autogamy) and a small degree of cross pollination (xenogamy)

Pollination requirements

Flowers of cultivated forms are monoecious and self-pollinated. Cross pollination by insects, particularly large-bodied bumblebees and carpenter bees increases yield and seed quality.

Flowering and harvest periods

Flowering: Year round

Harvest: 80 to 100 days after planting

Main varieties grown in Brazil

BGF13013, BRS Agreste, BRS Ametista, BRS Ártico, BRS Campeiro, BRS Embaixador, BRS Estilo, BRS FC402, BRS Notável, BRS Pitanga, BRS Pontal, BRS Realce, BRS Requinte BRS Vereda, BRSMG Madreperola, BRSMG União, Jalo Precoce, Pérola

Other information

Insect pollination usually increases the number of seeds per pod. The number of pods depends on each variety and mostly on its auto pollination rate.

The morphology of the flower fits better to large bees with long tongues than to small bees with short tongues. Therefore, farmers should promote large bees with long tongues to optimize the pollination of the common bean. These can be carpenter bees, orchid bees, leafcutter bees or long-horned bees. Leafcutter bees can be promoted by the use of bee houses, see picture on page 113.

Flower description

Flowers are hermaphrodite and bilaterally symmetrical. The tubular calyx is green and hairy. The corolla is white or pinkish white, with five petals, the posterior petal is outermost, the two lateral petals with long wings and the two anterior petals form a united keel. ♀ organ with one carpel. The ovary is superior, elongated, green, unilocular with numerous ovules. The style is long, bent at its base and terminates with the stigma. ♂ organ with nine stamens, enclosed within the keel and fused into a tube, one posterior stamen is free.

Flower visitors and pollinators

Common name	**Scientific name**	**Sociality**
Honeybee	*Apis mellifera*	Eusocial
Bumblebee	*Bombus atratus*	Social
Carpenter bee	*Xylocopa* sp.	Solitary
Long-horned bee	*Thygater analis*	Solitary
Leafcutter bee	*Megachile* sp.	Solitary

The carpenter bee *Xylocopa grisescens* on a common bean flower

References

Carpentieri-Pípolo et al. (2001); Free (1966); Ibarra-Perez et al. (1999); Shree et al. (1991)

Cotton/Algodão *Gossypium hirsutum* L.

Status: Naturalized, originates from northern Neotropics

Growing areas: AL, AM, BA, CE, ES, GO, MA, MG, MS, MT, PB, PE, PI, PR, RJ, RN, SE, SP, TO

Cultivation: Open plantations

Attractiveness score: 4

Pollinator dependency: Modest

Plant-mating system: Commonly self pollination (autogamy), but a mixed-mating system with geitonogamy and xenogamy occurs

Malvaceae

Pollination requirements

The hermaphrodite flowers of cultivated varieties are usually self-pollinating, additional cross pollination by bees increases cotton production. Bumblebees and carpenter bees are considerably more effective pollinators, though less frequent in flowers than other bee species.

Flowering and harvest periods

Flowering: Year round

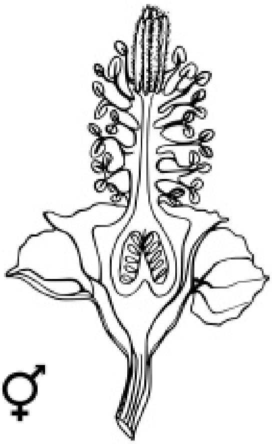
Harvest: Year round

Main varieties grown in Brazil

BRS 187, BRS 336, BRS 368RF, BRS Topázio, BRS Verde, IMA6501B2RF, IMA7201B2RF, IMA7501WS, TMG 11 WS, TMG 41 WS, TMG 42 WS, TMG 43 WS, TMG 81 WS, TMG 82 WS

Other information

Productivity of some varieties increases by approximately 20% when pollinated by bees. Pollination by honeybees resulted in more cotton bolls than passive self pollination. The cotton bolls of open-pollinated flowers were 1.2 times heavier than cotton bolls forming after wind pollination. The cotton bolls of hand cross-pollinated flowers were 1.3 times heavier than cotton bolls forming after passive self pollination.



Flower description

Flowers are hermaphrodite and radially symmetrical with three epicalyx bracts, five fused sepals and five free white petals. ♀ organ with three to five carpels fused into a superior ovary. The undivided style terminates in three to five stigmas. ♂ organ with 13 or more stamens fused into a tube around the pistil.

Flower visitors and pollinators

Common name	**Scientific name**	**Sociality**
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Paratrigona lineata*	Eusocial
Stingless bee	*Trigona spinipes*	Eusocial
Stingless bee	*Geotrigona mombuca*	Eusocial
Stingless bee	*Partamona cupira*	Eusocial
Stingless bee	*Partamona mulata*	Eusocial
Stingless bee	*Melipona quinquefasciata*	Eusocial
Stingless bee	*Tetragona clavipes*	Eusocial
Stingless bee	*Trigona hyalinata*	Eusocial
Stingless bee	*Frieseomelitta doederleini*	Eusocial
Stingless bee	*Trigona fuscipennis*	Eusocial
Stingless bee	*Frieseomelitta varia*	Eusocial
Stingless bee	*Trigona recursa*	Eusocial
Stingless bee	*Schwarziana quadripunctata*	Eusocial
Stingless bee	*Trigonisca* sp.	Eusocial
Bumblebee	*Bombus morio*	Social
Bumblebee	*Bombus atratus*	Social
Carpenter bee	*Xylocopa suspecta*	Solitary
Carpenter bee	*Xylocopa hirsutissima*	Solitary
Carpenter bee	*Xylocopa* sp.	Solitary
Small carpenter bee	*Ceratina gossypii*	Solitary
Small carpenter bee	*Ceratina* sp.	Solitary
Long-horned bee	*Melissoptila cnecomala*	Solitary
Long-horned bee	*Melissoptila pubescens*	Solitary
Long-horned bee	*Florilegus festivus*	Solitary
Oil-collecting bee	*Centris scopipes*	Solitary
Oil-collecting bee	*Centris collaris*	Solitary
Oil-collecting bee	*Epicharis bicolor*	Solitary

List continues at p. 119

References

Bozbek et al. (2008); Cusser et al. (2016); Eisikowitch & Loper (1984); FAO (2018); Heuberger et al. (2010); McGregor (1959); Moffett (1977); Moffett et al. (1975); Moffett et al. (1980); Pires et al. (2014, 2015); Rhodes (2002); Waller et al. (1985a,b)

Cowpea/Feijão-caupi *Vigna unguiculata* (L.) Walp.

Fabaceae

Status: Cultivated, was first domesticated in Ghana

Growing areas: CE, PB, PI, PE, RN, MS, MT, MG, RJ, SP, PR, AL, SE, BA

Cultivation: Open fields

Attractiveness score: 3

Pollinator dependency: Little

Plant-mating system: Cleistogamous, self pollination (autogamy) and cross pollination (xenogamy)

Pollination requirements

Cowpea flowers produce nectar, which is attractive for insects, especially bees. However, flowers are usually auto-pollinated, before they open. Insect flower visitors increase pollen deposition, especially on flowers that failed to self pollinate and therefore increase seed set per pod and number of pods.

Flowering and harvest periods

Flowering: Year round

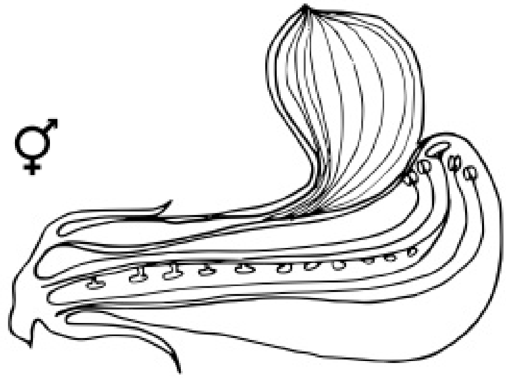
Harvest: 60 to 90 days after planting

Main varieties grown in Brazil

Arigozinho, BR 17 – Gurgueia, BR3 – Tracuateua, Branco de praia, BRS Amapá, BRS Aracê, BRS Cauamé, BRS Guariba, BRS Itaim, BRS Juruá, BRS Marataoã, BRS Mazagão, BRS Milênio BRS Novaera, BRS Pajeú, BRS Paraguaçu, BRS Potengi, BRS Rouxinol, BRS Tumucumaque, BRS Urubuquara, BRS Xiquexique, Corujinha, Manteiguinha, Manteiguinha roxo, Mudubim de Rama, Preto de praia, Quarentão, Roxinho de praia

Other information

Seed number, dry weight of seed/pod, pod length and the percentage of normal form seed/pod decreases with insect exclusion from flowers. Insect exclusion decreases fruit production rate from 62% to 48% and the proportion of healthy seeds from 98% to 76%.



Flower description

Flowers are hermaphrodite and zygomorphic with five free sepals and petals, the upper petal is outermost, the two side petals have long wings and the two lower petals form a united keel. ♀ organ with multiple carpels fused and an insertion in the terminal style. ♂ organ with one out of nine stamen longer than the others and with free anthers.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Melipona subnitida*	Eusocial
Stingless bee	*Trigona fuscipennis*	Eusocial
Bumblebee	*Bombus brevivillus*	Social
Carpenter bee	*Xylocopa cearensis*	Solitary
Carpenter bee	*Xylocopa grisescens*	Solitary
Leafcutter bee	*Megachile* sp.	Solitary
Beetle	*Lagria villosa*	Solitary

Stingless bees (*Trigona fuscipennis*) on a cowpea flower

References

Araújo (2012); Asiwe (2009); D'Andrea et al. (2007); Fohouo et al. (2009); Ige et al. (2011); Sheahan (2012); Venter (1996)

Cupuassu/Cupuaçu *Theobroma grandiflorum* (Willd. ex Spreng.) K.Schum.

Malvaceae

Status: Native

Growing areas: AC, AM, PA, RO, BA

Cultivation: Shade (Tropical forest)

Attractiveness score: 2

Pollinator dependency: High

Plant-mating system: Cross pollination (xenogamy)

Pollination requirements

Self-incompatible and requires cross pollination by insects. The main effective pollinators are bees that move between trees, but ants and aphids are also considered to be pollinators.

Flowering and harvest periods

Flower: July to September

Harvest: October to June

Main varieties grown in Brazil

Cupuaçu-mamau, Cupuaçu-mamorana, Cupuaçu-redondo

Other information

Hand pollination resulted in a much higher fruit set than open pollination, indicating that lack of effective pollination is a reason for low yields. Experimental pollination using compatible pollen grains have shown that a flower which receives 60 compatible pollen grains has 20% probability of setting fruit; a flower which receives more than 400 pollen grains always sets fruit. However, fewer than 2% of naturally-pollinated Cupuassu flowers have more than 50 pollen grains on their stigmas. Cupuassu varieties with many flowers, blooming for a long time per tree, might increase the attractiveness of the tree for pollinators and with this the chance that many and diverse pollinating species are available. In general, the pollination system of cupuassu is not well studied, but the more insect species visit the flowers the higher the fruit set should be. Therefore, conserving this beneficial insects should be valuable in commercial cupuassu production systems.

Flower description

Flowers are hermaphrodite and radially symmetrical with a perianth of five thick fleshy, boat-shaped, whitish green and tomentose sepals and five thick, whitish petals terminating in purple tongues. ♀ organ with five carpels fused into a superior, tomentose ovary, with a yellowish style. ♂ organ with ten stamens including five infertile, long, lanceolate and purple stamen and five fertile stamen with short three parted anthers.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Stingless bee	*Plebeia minima*	Eusocial
Stingless bee	*Tetragonisca angustula*	Eusocial
Stingless bee	*Trigona pallens*	Eusocial
Stingless bee	*Aparatrigona impunctata*	Eusocial
Ant	*Wasmannia* sp.	Eusocial
Beetle	*Baris* sp.	Solitary
Beetle	*Chrysomelidae*	Solitary

Ant on a cupuassu flower

Stingless bee (*Trigona* sp.) in a cupuassu flower

References

Alves et al. 2003; Calzavara et al. (1984); Falcao & Lleras, E (1983); Maués et al. (2000); Venturieri (1993); Venturieri (1994); Venturieri (2011); Venturieri & Ribeiro Filho (1995)

Guava/Goiaba *Psidium guajava* L.

Status: Native

Growing areas: AC, AM, AL, BA, CE, MA, PE, PI, SE, MS, MT, ES, MG, RJ, SP, PR, RS, SC, PB, RN

Cultivation: Open plantations

Attractiveness score: 3

Pollinator dependency: Modest

Plant-mating system: Self pollination (autogamy, geitonogamy) and cross pollination (xenogamy)

Pollination requirements

Self pollination by insects or wind is possible, and isolated trees often set satisfactory fruit numbers without cross pollination. Cross pollination is frequently aided by bees and other pollen carrying insects.

Flowering and harvest periods

Flowering: September to November

Harvest: December to March

Main varieties grown in Brazil

Branca de Valinhos, Cortibel, IPA B-22, Kumagai, Ogawa, Paluma, Pedra Branca, Pedro Sato, Pentecostes, Pirassununga Vermelha, Rica, Ruby Supreme, Sassaoka, Tailandesa

Other information

The exclusion of pollinators other than wind reduces fruit set. Cross pollination increases yield. The presence of biotic pollinators like *Apis mellifera* and other bees promotes cross pollination in guava orchards and maximizes crop productivity. Guava trees are commonly planted in private gardens. Here they can be pollinated by hand with a brush, preferably with pollen of another guava tree but as self pollination leads to fruit set, the transport of pollen within a tree can also increase the production. As guava is also consumed by wildlife, the trees contribute to conserve biodiversity in private gardens and public parks. When planting guava trees it is recommended to plant at least two trees to optimize pollination.

Flower description

Flowers are in cauliflorous inflorescences, hermaphrodite and radially symmetrical with four to six sepals and four to six white petals. ♀ organ with an inferior ovary, three to five locular and one long style that terminates in capitate stigma. ♂ organ with many stamens in many circles around the stigma and ellipsoid anthers.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Melipona mandacaia*	Eusocial
Stingless bee	*Partamona seridoensis*	Eusocial
Stingless bee	*Trigona spinipes*	Eusocial
Stingless bee	*Frieseomelitta doederleini*	Eusocial
Stingless bee	*Partamona cupira*	Eusocial
Stingless bee	*Tetragona dorsalis*	Eusocial
Stingless bee	*Trigona amalthea*	Eusocial
Stingless bee	*Trigona* sp.	Eusocial
Oil-collecting bee	*Centris aenea*	Solitary
Carpenter bee	*Xylocopa cearensis*	Solitary
Carpenter bee	*Xylocopa* sp.	Solitary
Other bee	*Exomalopsis analis*	Solitary

References

Alves & Freitas (2006, 2007); Freitas & Alves (2008); Hamilton, & Seagrave-Smith (1959); Hedström (1988); Siqueira et al. (2012); Tchuenguem Fohouo et al. (2007); Viana (2008)

Kiwifruit/Kiwi *Actinidia deliciosa* (A.Chev.) C.F.Liang & A.R.Ferguson

Status: Cultivated

Growing areas: SP, SC, PR, RS

Cultivation: Open plantations

Attractiveness score: 4

Pollinator dependency: Essential

Plant-mating system: Cross pollination (xenogamy), only few varieties are self fertile

Pollination requirements

Kiwifruit is dioecious and requires pollen transportation by wind or insects between male and female plant individuals. Although wind pollination is common, it is insufficient for a successful fruit yield. Entomophilous pollination is essential to ensure high yields. With increasing bee visitation rates pollen deposition on stigmas, seed numbers and fruit weight increases.

Flowering and harvest periods

Flower: November to December

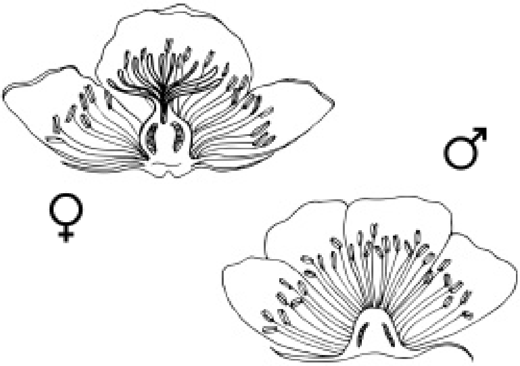
Harvest: January to February

Main varieties grown in Brazil

Abbott, Allison, Bruno, Hayward, Monty, Tomuri

Other information

Wind pollination results in 15% fruit set, while hand cross pollination reaches over 95% fruit set and open pollination 92% fruit set, in one study. Open pollination increases fruit weight on average by 25% compared to wind pollination. While syrphids and solitary bees are not known to pollinate kiwifruit, *Apis mellifera* is an effective kiwifruit pollinator. In New Zealand, but also Argentina, commercial kiwi production applies pollen spraying with different forms of suspensors. Pollen spraying in these countries includes products available to maintain the viability of kiwi pollen in a water-based suspension. With this suspension the spraying of pollen can be done under various weather conditions.



Flower description

Flowers are dioecious and radially symmetrical with six white petals. ♀ flower with many carpels fused forming the style which terminates into radially organized stigmas. A wreath of anthers sheding sterile pollen surrounds the ovary. ♂ flower with many long stamens in a wreath and with no style.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Bumblebee	*Bombus* sp.	Social
Solitary bee	*Leioproctus* sp.	Solitary

References

Anonymous (1984); Blanchet et al. (1991); Clinch (1984); Clinch & Heath (1985); Clinch & Houten A.T. (1985); Costa et al. (1993); Donovan & Read (1990); Gonzalez et al. (1998); Goodwin et al. (1997); Howpage et al. (2001); Jay & Jay (1983); MacFarlane & Ferguson (1984); Manino et al. (1996); Miñarro & Twizell (2015); Palmer-Jones & Clinch (1974); Palmer-Jones & Clinch P.G. (1975); Palmer-Jones & Clinch (1976); Sharma et al. (2013); Simonetto & Grellmann (1998); Testolin et al. (1991); Vassiere et al. (1996)

Lychee/Lichia *Litchi chinensis* Sonn.

Sapindaceae

Status: Cultivated, native to Southeast Asia

Growing areas: SP, PR, MG, GO

Cultivation: Open plantations and gardens

Attractiveness score: 4

Pollinator dependency: Little

Plant-mating system: Cross pollination (xenogamy) and self pollination (geitonogamy)

Pollination requirements

Lychee flowers are monoecious with protandrous hermaphroditic dichogamy. Male and female flowering stages overlap within one plant individual, therefore, self pollination occurs, but cross pollination is much more common. Fruit set requires the transfer of pollen from male flowers to the stigma of female flowers. Lychee flowers are entomophilous and usually pollinated by bees, flies, ants and wasps.

Flowering and harvest periods

Flower: August to September

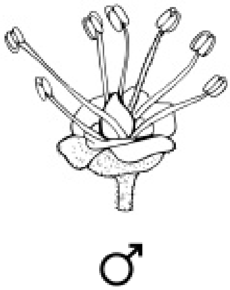
Harvest: November to January

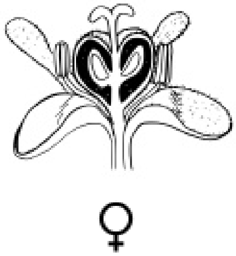
Main varieties grown in Brazil

Bengal, Brewster, Groff, Sweet Clift

Other information

Wind pollination resulted in 23, hand cross pollination in 45 and open pollination in 29 fruits/panicle, suggesting a pollination deficit in commercial plantations. Honeybees constitute 78% of the lychee-pollinating insects. Fruit and seed weight is higher in cross-pollinated fruits than in self-pollinated fruits. Lychee can produce commercially without pollinators, but different beneficial insects frequently visit flowers. Therefore, if pesticides, especially insecticides, are applied their spraying during bloom needs to be avoided. The addition of honeybees to lychee plantations increased fruit set. Honeybees are managed for lychee production in India, Madagascar and other places of the world. It is recommended to use 5 to 10 honeybee colonies per ha. Lychee honey is known for a delicate scent reminiscent of roses.





Flower description

Lychee inflorescences have many male and female flowers on one panicle. Flowers are monoecious and radially symmetrical without petals and with four to five tomentose sepals which open early. ♀ flower with a short, well developed pistil. Ovary is long with two to four carpels, two lobes of the sticky stigma open down into a vertical cleft. Some flowers with five to eight short stamen and anthers containing little pollen. ♂ flowers with six to eight stamen that are much longer than the sepals and with hairy filaments. The anthers are elliptical and glabrous (bald, no hair). The rudimentary pistil is lacking both stigma and style.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Tetragonisca angustula*	Eusocial
Stingless bee	*Trigona* sp.	Eusocial
Stingless bee	*Melipona* sp.	Eusocial
Sweat bee	*Halictus* sp.	Solitary/Social
Ladybird	*Coccinella septempunctata*	Solitary
Lady beetle	*Harmonia axyridis*	Solitary

Stingless bee (*Tetragonisca angustula*) approaching a lychee flower

Solitary bee (*Halictus* sp.) on lychee flowers

References

Abrol (2006); Ali et al. (2013); Batten (1986); Batten & McConchie (1995); Mandal et al. (2016); Matos (2012); Morton (1987); Poonam et al. (2010); Rai et al. (2017); Kuman (2014); Singh et al. (2017); Somnuk & Suavansri (2005); Srivastava et al. (2017); Stern & Gazit (1996)

⇧

Mango/Manga *Mangifera indica* L.

Status: Cultivated, originates from Southeast Asia

Growing areas: All states of Brazil

Cultivation: Open plantations

Attractiveness score: 4

Pollinator dependency: High

Plant-mating system: Diurnal protogynous dichogamy limits autogamous self pollination and increases cross pollination (xenogamy), common varieties are self-incompatible and require cross pollination in few varieties like 'Tommy Atkins' and self pollination in 'Keitt'.

Pollination requirements

Mango fruit set is generally low compared to the number of fertile flowers (only 1-5% of flowers set fruit). Pollination of various insect groups occurs. Especially highly mobile and abundant species such as honeybees and flies are expected to be efficient pollinators. Wind is under debate due to the short viability of pollen (12h) and stickiness of pollen especially in the beginning of anthesis. As mango varieties range from self-sterile to self-pollinating and fruit set is generally very low, further research and variety-specific information is needed.

Flowering and harvest periods

Flowering: Year round

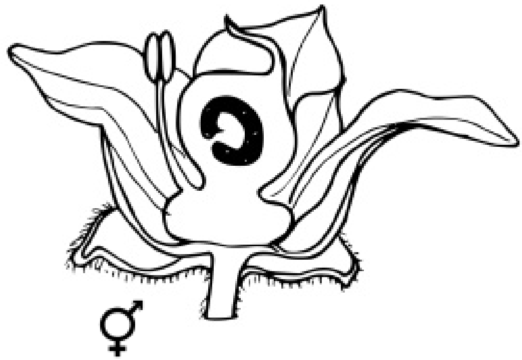
Harvest: Year round

Main varieties grown in Brazil

Bourbon, Coitê, Espada, Haden, Keitt, Kent, Ourinho, Palmer, Rosa, Tommy, Van dyke

Other information

Pollinator contribution to mango fruit set is estimated at about 50% of total fruit set production. In Brazil, native flies and honeybees have been documented as valuable pollinators of mango trees.



Flower description

Flowers are organized in panicles bearing 500 to 10.000 flowers including both male and hermaphrodite, radially symmetrical flowers with usually five pubescent sepals, usually five greenish yellow or pale cream short petals, and a prominent disk, functioning as nectary, between the petals and stamens. Colour of sepals and petals changes with age from bright to dark. ♀ organ with spherical ovary and a style that emerges from one side. ♂ organ with usually one longer fertile stamen and four shorter staminodes born from the disk, ♂ flowers without gynoecium.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Melipona* sp.	Eusocial
Small carpenter bee	*Ceratina* sp.	Solitary
Carpenter bee	*Xylocopa* sp.	Solitary
Sweat bee	*Halictus* sp.	Solitary/Social
Housefly	*Musca domestica*	Solitary
Blow fly	*Chrysomya megacephala*	Solitary
Butterfly	*Papilio polytes*	Solitary
Ladybird	*Coccinella septempunctata*	Solitary

Fly on mango flowers

References

Amin et al. (2015); Bally (2006); Carvalheiro et al. (2010); Fajardo et al. (2008); Gajendra (1989); Huda et al. (2015); Kiill (2008); Kumari et al. (2014); Ramírez & Davenport (2016); Singh (1984); Sung et al. (2006); Tayeng & Gogoi (2016)

Melon/Melão *Cucumis melo* L.

Cucurbitaceae

Status: Cultivated, originates from Southwest Asia

Growing areas: AL, BA, CE, MA, PB, PE, PI, RN, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC

Cultivation: Open plantations

Attractiveness score: 4

Pollinator dependency: Essential

Plant-mating system: Usually self-pollinated (geitonogamy) and cross pollination (xenogamy)

Pollination requirements

Melon plants are self-pollinated, but insect pollination is essential for pollen transfer from anthers to stigmas, within the hermaphrodite flowers or between male and hermaphrodite or female flowers.

Flowering and harvest periods

Flowering: Year round

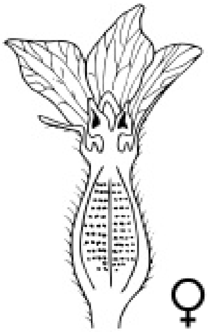
Harvest: Year round

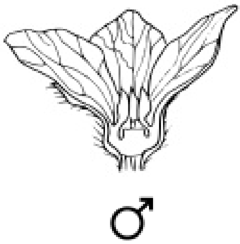
Main varieties grown in Brazil

Yellow (Natal, Goldex, Dali), Cantaloupe (Caribbean Gold, Rangers, Pitayo), Charentais (Magrite, Magistro), Galia (DRG 3228, Eldoor, Gladial), Piel del Sapo (Grand Prix, Ricura, Finura), Honey Dew (Dino, Orange Country

Other information

Many bee species show potential to pollinate *Cucumis melo* and to influence its productivity, but *Apis mellifera* is the managed species used in Brazilian plantations. Pollination by honeybees can increase yield per hectare and improve the size, quality and marketability of the fruit. In a recent study it was shown that different Brazilian melon varieties (agronomic types) (Cantaloupe, Charentais, Galia, Piel de sapo, Yellow) have different volatile organic compounds (VOCs). Some are attractive and some repellent for honeybees. Also, nectar content varies from male to hermaphrodite flowers inducing honeybees to favour the latter ones. It is therefore suggested to breed new varieties with VOC and nectar content attractive for bees and other pollinating insects in Brazil.





Flower description

Flowers are monoecious or hermaphrodite, commonly male and hermaphrodite or female at the same plant. Hermaphrodite and female flowers are single, male flowers smaller and in clusters at the same plant, both are radially symmetrical with five yellow petals. ♀ organ with a three-lobed stigma on a short style and an inferior ellipsoid ovary. ♂ organ with five stamens and ♂ flowers without ovary.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Trigona fulviventris*	Eusocial
Stingless bee	*Trigona pallens*	Eusocial
Stingless bee	*Trigona spinipes*	Eusocial
Stingless bee	*Plebeia* sp.	Eusocial
Bumblebee	*Bombus* sp.	Social
Long horned bee	*Peponapis* sp.	Solitary
Long-horned bee	*Melissodes* sp.	Solitary
Small carpenter bee	*Ceratina* sp.	Solitary
Leafcutter bee	*Megachile* sp.	Solitary
Sweat bee	*Augochlora* sp.	Solitary/Social
Sweat bee	*Pseudaugochloropsis* sp.	Solitary/Social
Sweat bee	*Agapostemon* sp.	Solitary/Social
Sweat bee	*Halictus* sp.	Solitary/Social
Other bee	*Exomalopsis* sp.	Solitary

References

Bomfim et al. (2016); Bomfim et al. (2019); Fernandes et al. (2019); Gomez et al. (2016); Goodell & Thomson (2007); Grewal & Sidhu (1978); Kaziev & Seidova (1965); Kiill et al. (2014, 2015, 2016); Lemasson (1987); Mann (1954); McGregor et al. (1965); McGregor & Todd (1952); Meléndez-Ramirez et al. (2002); Mouzin et al. (1980); Nerson (2009); Ribeiro et al. (2015); Stanghellini et al. (2002); Taylor (1955); Tschoeke et al. (2015); Williams (1987); Wilson et al. (2016)

Oil palm/Dendê *Elaeis guineensis* Jacq.

Status: Naturalized, originates from West and Southwest Africa

Growing areas: BA, PE, RN, PA, AM

Cultivation: Open plantations

Attractiveness score: 4

Pollinator dependency: High

Plant-mating system: Cross pollination (xenogamy)

Pollination requirements

Elaeis guineensis requires cross pollination through pollen transport from a neighbouring tree by wind or pollinators to set fruit. Beetles (Coleoptera) are the most numerous, diverse and commonly associated pollinators of oil palm and therefore most valuable for crop production.

Flowering and harvest periods

Flowering: Year round

Harvest: Year round

Main varieties grown in Brazil

Dura, Psifera, Tenera

Other information

The weevil genus *Elaeidobius* is a highly effective pollinator and specified on oil palm species. Pollination of oil palm by *Elaeidobius kamerunicus* is well studied and known to increase fruit set. Pollination of *Elaeidobius* sp. weevils is therefore essential for high production. The application of broad spectrum insecticides to control insect pest species also kills the pollinating weevils. Therefore, if insecticides are applied their application should be suspended during oil palm blooming and the weeks before blooming. As the weevils are living in the plantations all year around, the necessity of insecticides needs careful consideration. Moreover, honeybees frequently visit oil palm flowers, to avoid honey contamination, also pesticides should not be applied during the main flowering period in commercial plantations. A sustainable solution might be the use of natural enemies to control insect pests.

Flower description

Flowers are monoecious with radially symmetrical male and zygomorph female flowers with three sepals and petals. ♀ flower with sterile stamens and a three-celled ovary with three spreading stigmas. ♂ flower with six stamens and a small, sterile pistil.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Beetle	*Elaeidobius kamerunicus*	Solitary
Beetle	*Elaeidobius subvittatus*	Solitary
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Trigona fulviventris*	Eusocial
Stingless bee	*Trigona* sp.	Eusocial
Leafcutter bee	*Megachile* sp.	Solitary
Carpenter bee	*Xylocopa* sp.	Solitary
Other bee	*Lithurgus* sp.	Solitary

Curculionid beetles on oil plam flowers

Honeybees (*Apis mellifera*) on oil palm flowers

References

Barcelos et al. (2015); Meléndez & Ponce (2016); Mayfield (2005); Moura et al (2008); Siregar et al. (2016)

Okra/Quiabo *Abelmoschus esculentus* (L.) Moench

Status: Cultivated

Growing areas: MG, RJ, SP

Cultivation: Open fields

Attractiveness score: 3

Pollinator dependency: Modest

Plant-mating system: Primarily self pollination (autogamy and geitonogamy) and a small degree of cross pollination (xenogamy)

Malvaceae

Pollination requirements

Okra flowers are hermaphrodite and auto pollination is common, but cross pollination by insects also occurs. Auto pollination leads to 100% fruit set (pods). However, insect pollination increases the number of seeds per pod, the seed weight and pod length, thus increases yield.

Flowering and harvest periods

Flower: Year round

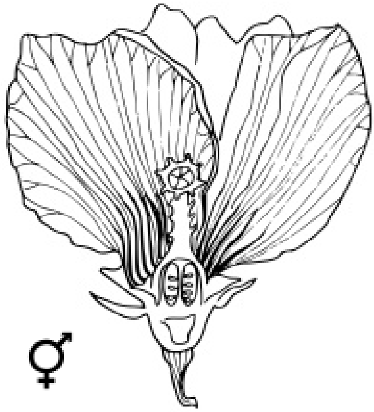
Harvest: Year round

Main varieties grown in Brazil

Alecrim, Amarelinho, Campinas 1 (IAC-4075), Campinas 2 (IAC-4076), Chifre-de-veado, Green Velvet, Santa Cruz 47, White Velvet

Other information

Despite okra flowers auto pollinate to set fruits, insect pollinators, especially bees, contribute to increase yield as they transfer more pollen grains to the stigma and promote self and cross pollination. Hence, although the number of fruits is usually not increased, the fruits become larger, heavier and bear more seeds after insect pollination. To increase yields at the small scale of a private garden, okra can be hand pollinated. Okra flowers open for one day only. Therefore, bud development needs to be observed carefully. For hand pollination pollen from the same or different plant individuals can be transferred using a slightly oily or wet (distilled water) brush or cotton swap. In hot weather and moist soil the fruit will develop in a few days.



Flower description

Flowers are hermaphrodite and radially symmetrical with eight to 12 bracts, five sepals and five free petals forming a white to cream coloured Hibiscus-like corolla with a dark to pinkish centre. ♀ organ with superior ovary with five to ten fused styles and a dark red stigma. ♂ organ with many stamens fused into a tube around the pistil.

Flower visitors and pollinators

Common name	**Scientific name**	**Sociality**
Honeybee	*Apis mellifera*	Eusocial
Bumblebee	*Bombus* sp.	Social
Leafcutter bee	*Megachile* sp.	Solitary
Carpenter bee	*Xylocopa* sp.	Solitary

Honeybee (*Apis mellifera*) on an okra flower

References

Azo'o et al. (2011); Ghzawi et al. (2003); Ige & Eludire (2014); Malerbo-Souza et al. (2001); Njoya et al. (2005); Purewal & Randhawa (1947); Shalaby (1998); Singh et al. (2017)

Papaya/Mamão *Carica papaya* L.

Caricaceae

Status: Naturalized, originates from the northern Neotropics

Growing areas: All states of Brazil

Cultivation: Open plantations

Attractiveness score: 4

Pollinator dependency: Little

Plant-mating system: Self pollination (geitonogamy) but cross pollination (xenogamy) can also occur

Pollination requirements

Commercially grown papaya flowers are usually hermaphrodite highly dimorphic, but also trees with only male or female flowers occur. Papaya is facultative self-pollinating with a low cross pollination rate by pollinators.

Flowering and harvest periods

Flowering: Year round

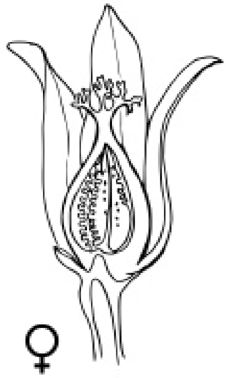
Harvest: Year round

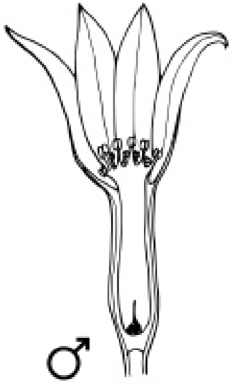
Main varieties grown in Brazil

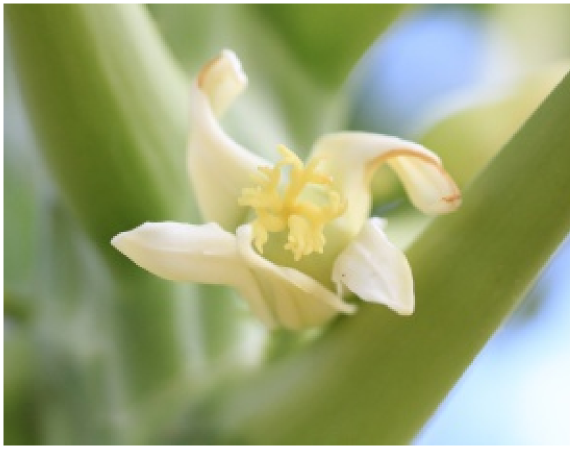
Formosa (Tainung nº 1, Tainung nº 2'), Mamão Comum, Mamão Papaia, Solo (Sunrise Solo, Improved Sunrise Solo cv 72/12')

Other information

Trees within and between varieties can be male, female or hermaphrodite. However commercially grown trees are mostly hermaphrodites. Papaya does not have typical bee-pollinated flowers, but they are visited by bees. The primary pollinators, around the world, are hawkmoths and some skipper butterflies, but for Brazil information about pollinator species is scarce. Cross pollination of pistillate flowers by insects produces fruit of high quality. Even though several pest insects can be problematic in commercial papaya production, the use of insecticides at least during flowering should be avoided to protect the nocturnal moth and diurnal bee flower visitors.







Flower description

Flowers can be dioecious, male and female on different plant individuals, or hermaphrodite, but allways radially symmetrical with five petals. ♀ flower with large functional pistil, ovoid ovary and no stamens. ♂ flower with ten stamens in two rows, with a pistillode. Hermaphrodite flowers with a combination of both functional ♂ and ♀ organs.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Tetragonisca angustula*	Eusocial
Hawk moth	*Erinnyis ello*	Solitary
Butterfly	*Papilio polytes*	Solitary
Butterfly	*Phoebis sennae*	Solitary
Beetle	*Acanthinus aequinoctialis*	Solitary
Ant	*Monomorium floricola*	Eusocial
Stingless bee	*Trigona* sp.	Eusocial
Carpenter bee	*Xylocopa* sp.	Solitary
Hoverfly	*Mesograpta* sp.	Solitary
Ant	*Brachymyrmex*	Eusocial
Ant	*Pheidole* sp.	Eusocial
Ant	*Solenopsis* sp.	Eusocial
Thrips	*Frankliniella* sp.	Solitary

References

Allan (1963); Avila Jr. et al. (2012); Damasceno Jr. et al. (2009); Dey et al. (2016); Garrett (1995); Marin-Acosta (1969); Martins & Johnson (2009); Morrisen (1995)

Passifloraceae

Passion fruit/Maracujá *Passiflora edulis* Sims

Status: Native

Growing areas: AM, PA, TO, AL, BA, CE, MA, PB, PE, PI, RN, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC

Cultivation: Open plantations

Attractiveness score: 4

Pollinator dependency: Essential

Plant-mating system: cross pollination (xenogamy)

Pollination requirements

Passiflora flowers are self-incompatible and show protandrous dichogamy, by releasing pollen before the stigma is receptive. The flowers of *P. edulis* have characteristics adapted to suit pollination by large bees, carpenter bees (*Xylocopa* spp.) are considered the most effective pollinators of commercial passion fruit due to their morphological and behavioural characteristics.

Flowering and harvest periods

Flowering: Year round

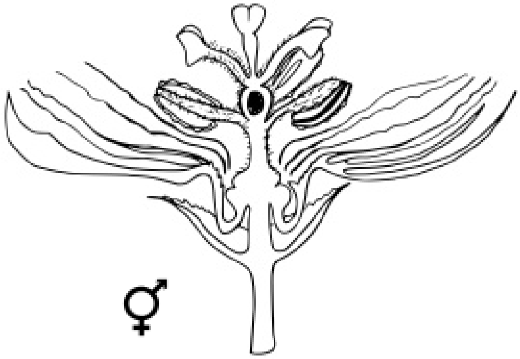
Harvest: Year round

Main varieties grown in Brazil

BRS Gigante Amarelo, BRS Ouro Vermelho, BRS Rubi do Cerrado, BRS Sol do Cerrado, FB 200, Golden Star, Marília

Other information

An important feature of the passion fruit flower is the androgynophore, an extension of the flower receptacle which elevates the stigma and stamens high above the petals. This requires large bodied insects, such as carpenter bees, large orchid bees or bumblebees, to touch the reproductive organs while consuming nectar. The absence of carpenter bees implies low production or producers to hand pollinate the flowers, which increases production costs. Alternatively, the protection of dead wood and old trees adjacent to the field can naturally attract carpenter bees by providing nesting structures.



Flower description

Flower is hermaphrodite and radially symmetrical with five ovate, white petals and sepals and whorls of coronal appendages between the perianth and stamens. ♀ organ with three carpels with three styles and stigmas and a superior ovary. ♂ organ with five stamens.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Trigona spinipes*	Eusocial
Stingless bee	*Frieseomelitta varia*	Eusocial
Stingless bee	*Paratrigona lineata*	Eusocial
Stingless bee	*Tetragonisca angustula*	Eusocial
Stingless bee	*Trigona hyalinata*	Eusocial
Bumblebee	*Bombus pauloensis*	Social
Bumblebee	*Bombus morio*	Social
Carpenter bee	*Xylocopa suspecta*	Solitary
Carpenter bee	*Xylocopa cearensis*	Solitary
Carpenter bee	*Xylocopa hirsutissima*	Solitary
Carpenter bee	*Xylocopa grisescens*	Solitary
Carpenter bee	*Xylocopa brasilianorum*	Solitary
Carpenter bee	*Xylocopa frontalis*	Solitary
Carpenter bee	*Xylocopa ordinaria*	Solitary
Carpenter bee	*Xylocopa* sp.	Solitary
Oil-collecting bee	*Centris scopipes*	Solitary
Oil-collecting bee	*Centris longimana*	Solitary
Oil-collecting bee	*Epicharis flava*	Solitary
Oil-collecting bee	*Epicharis bicolor*	Solitary
Oil-collecting bee	*Centris denudans*	Solitary
Oil-collecting bee	*Centris lutea*	Solitary
Oil-collecting bee	*Centris flavifrons*	Solitary
Oil-collecting bee	*Centris sponsa*	Solitary
Oil-collecting bee	*Centris dorsata*	Solitary
Oil-collecting bee	*Centris similis*	Solitary
Orchid bee	*Eulaema nigrita*	Solitary

List continues at p. 120

References

Baran et al. (2017); Bezerra et al. (2019); Freitas, & Oliveira Filho (2001, 2003); Freitas et al. (2009); Gaglianone (2008); Hoffmann et al. (2000); Kiill (2008); Oliveira (2008); Silva & Freitas (2018); Silveira et al. (2012); Siqueira et al. (2009); Yamamoto et al. (2012)

Peach/Pêssego *Prunus persica* (L.) Batsch

Status: Cultivated, originates from Northwest China

Growning areas: BA, DF, ES, MG, RJ, SP, PR, RS, SC

Cultivation: Open plantations

Attractiveness score: 5

Pollinator dependency: High

Plant-mating system: Self pollination (autogamy, geitonogamy) in most varieties

Pollination requirements

Most varieties of peach are pollinated by honeybees and wild bees, transporting pollen within and between flowers.

Flowering and harvest periods

Flower: July to September

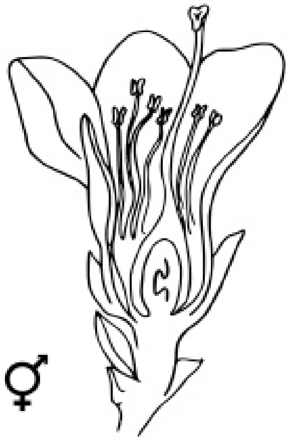
Harvest: November to December

Main varieties grown in Brazil

Ágata, Ametista, Barbosa, BR-2, BR3, BR-6, BRS Rubimel, Capdebosq, Cerrito, Charme, Chimarrita, Chinoca, Chiripá, Chirua, Chula, Coral, Coral, Della Nona, Diamante, El dorado, Eldorado, Esmeralda, Farrapos, FLA (13-72), Flordaprince, Flordasun, Granada, Jade, Leonense, Maciel, Maciel, Magno, Marfim, Marli, Marli, Morro Redondo, Ônix, Pampeano, Pearl, Pilcha, Planalto, Precocinho, Premier, Riograndense, Safira, Sentinela, Sentinela, Sinuelo, Sulina, Vanguarda, Vila Nova

Other information

There is little information about peach pollination in Brazil. Depending on the varieties autogamous self pollination and wind pollination results in 7 to 35% fruit set. However, also depending on the variety pollination by *Apis mellifera* may increase fruit set up to 66%. Several wild bee species are visiting peach flowers and may complement honeybee pollination in space and time. Therefore, flower resources should be available in peach orchards or their surroundings. Bee houses can also be established close to the orchards to promote beneficial solitary bees and wasps.

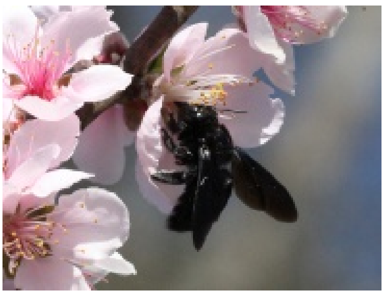


Flower description

Flowers are hermaphrodite and radially symmetrical with five hairy sepals and five pink petals. ♀ organ with one free carpel, composed of a long style terminating in a round stigma. ♂ organ with about 20 long stamens in three whorls.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stinglees bee	*Melipona* sp.	Eusocial
Stinglees bee	*Trigona spinipes*	Eusocial
Stinglees bee	*Trigona* sp.	Eusocial
Bumblebee	*Bombus* sp.	Social
Carpenter bee	*Xylocopa* sp.	Solitary
Ladybird	*Coccinella septempunctata*	Solitary



Carpenter bee (*Xylocopa* sp.) on a peach flower

Stingless bee (*Trigona* sp.) on a peach flower

Honeybee (*Apis mellifera*) on a peach flower

References

Free (1993); Gariglio et al. (2009); Mayer et al. (2017); Mota & Nogueira-Couto (2002); Raj & Mattu (2014); Weinbaum et al. (1989); Zhang et al. (2015)

Pear/Pera *Pyrus communis* L.

Rosaceae

Status: Cultivated, originates from mediterranean Europe and West Asia

Growing areas: BA, MG, SP, PR, RS, SC
Cultivation: Open plantations

Attractiveness score: 3

Pollinator dependency: High

Plant-mating system: Primarily cross pollination (xenogamy), but self pollination and parthenocarpy can occur in some varieties

Pollination requirements

Most pear cultivars are self-incompatible and must be pollinated with pollen from a different cultivar. Therefore, pollination requires flowering times of different varieties to overlap and the presence of insect pollinators.

Flowering and harvest periods

Flowering: August to September

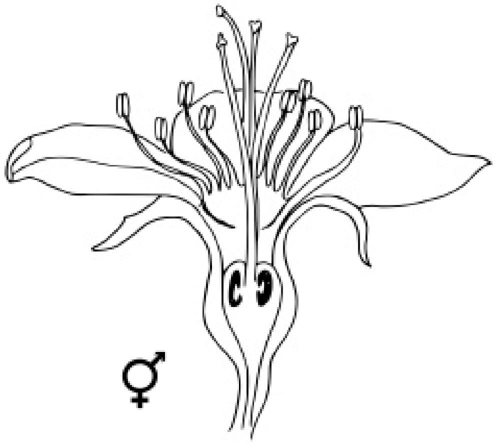
Harvest: November to December

Main varieties grown in Brazil

Asiática, D'água, Europeia, Seleta (IAC 16-28), Triunfo (IAC 16-34), Williams, D'anjou, Ercolini, Rocha Portuguesa

Other information

Wind pollination usually results in no or little fruit set, therefore the activity of insects, mainly bees, in orchards is essential for high yields. As different wild bee species frequently visit pear flowers they should be promoted in the surrounding or in the orchards to complement honeybee pollination. Care should be taken not to create habitat in places where pesticides are applied. In general for orchard crops, bee houses are an option to promote and conserve beneficial solitary bees and wasps and hence to conserve biodiversity.



Flower description

Flowers are hermaphrodite and radially symmetrical with five sepals and five white petals. ♀ organ with five carpels and an inferior ovary. ♂ organ with 10-30 stamens with dark red anthers.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Bumblebee	*Bombus* sp.	Social
Stingless bee	*Scaptotrigona* sp.	Eusocial
Carpenter bee	*Xylocopa* sp.	Solitary
Ladybird	*Coccinella septempunctata*	Solitary

Stringless bee (*Scaptotrigona* sp.) on a pear flower

Honeybee (*Apis mellifera*) on a pear flower

References

Free (1993); Hsieh et al. (2002); Jacquemart et al. (2006); Langridge & Jenkins. (1972); Lewis & Smith (1969); Maccagnani et al. (2003); Mayer & Lunden (1997); Monzon et al. (2004); Onarska et al. (2005); Quinet et al. (2016); Raj & Mattu (2014); Stern et al. (2004); Van den Eijnde (1996)

Persimmon/Caqui *Diospyros kaki* L.F.

Status: Cultivated, originates from China

Growing areas: AL, BA, CE, MA, PB, PE, PI, RN, SE, DF, GO, MS, MT, ES, MG, RJ, SP
Cultivation: Open plantations

Attractiveness score: 3

Pollinator dependency: Little

Plant-mating system: Self pollination (autogamy, geitonogamy) and cross pollination (xenogamy)

Pollination requirements

Persimmon plants are self-pollinating, but entomophilous pollination can improve fruit set and yield. Persimmon trees may bear parthenocarpic fruits and depending on the cultivar, the plants may be monoecious, dioecious or hermaphrodites.

Flowering and harvest periods

Flowering: September to December

Harvest: February to June

Main varieties grown in Brazil

Costata, Fuyu, Hachiya, Kaoru, Mikado, Okira, Pomelo, Rama Forte, Regina, Rubi, Taubaté

Other information

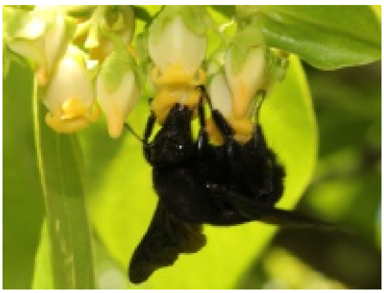
The 'Giombo' cultivar produces fruits parthenocarpically, these are seedless fruits which form without pollination. By contrast, the 'Fuyu' persimmon is visited by pollinators and produces fruits containing seed. In general, persimmon trees are variable and sometimes only bear female or only male flowers. Wild persimmon trees seem to be valuable pollinizers for commercial varieties and a low degree in wind pollination is described in some papers. Therefore, although we classified persimmon as little dependent on pollinators promoting and conserving bees in landscapes with persimmon production should stabilize persimmon production. Trees in gardens can also be pollinated by hand with a brush to secure high production.

Flower description

Flowers are hermaphrodite or more commonly female and male flowers separate. Flowers are radially symmetrical with a cream coloured four to five-lobed calyx tube. ♀ flowers with eight cream coloured carpels, four cellular ovary and eight infertile stamens. ♂ flowers with 16-24 pink tinged stamens in two rows on the petals.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Trigona* sp.	Eusocial
Oil-collecting bee	*Centris* sp.	Solitary
Carpenter bee	*Xylocopa* sp.	Solitary



Carpenter bee (*Xylocopa* sp.) on a persimmon flower

Stingless bee (*Trigona* sp.) on a persimmon flower

Honeybee (*Apis mellifera*) on a persimmon flower

References

Agustí. (2010); Campos et al. (2015); Chauhan et al. (2017); Free (1993); Giannini et al. (2015); Gould (1940); Hodgson (1938); Hodgson (1939); Martins &; Pereira (1989); McGregor (1976); Neuwald et al. (2009); Popenoe (1924); Ryerson (1927); Silva et al. (2016); Tessmer et al. (2014)

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Plum/Ameixa *Prunus domestica* L.

Status: Cultivated

Growing areas: RS, SC, SP, PR

Cultivation: Open plantations

Attractiveness score: 4

Pollinator dependency: High

Plant-mating system: Most varieties are cross-pollinated (xenogamy)

Pollination requirements

The flowers of most cultivars are self incompatible and require pollen from an appropriate pollinizer cultivar and insect activity for cross pollination. Wind is not a good pollen vector for *Prunus* spp.

Flowering and harvest periods

Flowering: August to September

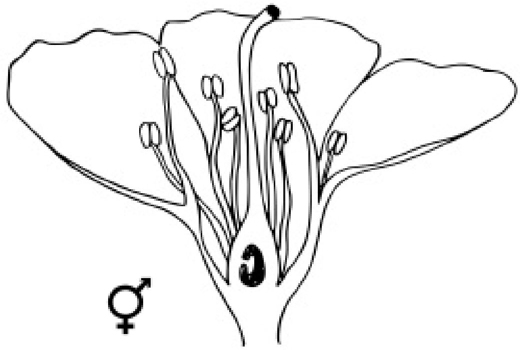
Harvest: November to December

Main varieties grown in Brazil

Americana, Bluefree, D'Agen, Damson, D'Ente 707, Européia e Selvagem, Japonesa, Magnific, Ornamental, President, Stanley, Sugar

Other information

Honeybees can improve fruit set and yield. Cross pollination with other cultivars results in the highest initial and final fruit set, revealing the importance of pollinizer trees and pollinating insects for the fruit set of plum. Various wild social and solitary bee species visit plum flowers in Brazil (own observations). As these bees likely complement pollination by honeybees they should be promoted and conserved in landscapes with plum orchards. Bee houses can be installed within the fields and natural habitat for nesting sites and flower resources providing bee forage before and after plum blooming can be created or conserved.



Flower description

Flowers are hermaphrodite and radially symmetrical with five pubescent sepals and five white petals. ♀ organ with one free carpel and a long style terminating in a round stigma. ♂ organ with about 20 long stamens and yellow anthers.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Melipona* sp.	Eusocial
Stingless bee	*Trigona* sp.	Eusocial
Bumblebee	*Bombus* sp.	Social
Ladybird	*Coccinella septempunctata*	Solitary

References

Benedek & Nyeki (1996); Dordević et al. (2016); Free (1993); Hassan et al. (2007); Jun & Chung (2007); Mattu (2014); Raj & Mattu (2014); Sapir et al. (2007); Wadhwa & Sihag (2015)

Pumpkin/Abóbora *Cucurbita maxima* Duchesne

Status: Cultivated, originates from South American species Cucurbita andreana

Growing areas: All states of Brazil

Cultivation: Open fields

Attractiveness score: 4

Pollinator dependency: Essential

Plant-mating system: Self pollination (geitonogamy) and cross pollination (xenogamy)

Pollination requirements

Cucurbita maxima is a monoecious plant, and pollen must be transferred from staminate male to pistillate female flowers to set fruit, either within the same or between different plants. Wind does not contribute to pollination, only insects, such as honeybees transfer pollen. Increased pollen deposition on the stigma may optimize pumpkin fruit size, weight and seed number.

Flowering and harvest periods

Flowering: Year round

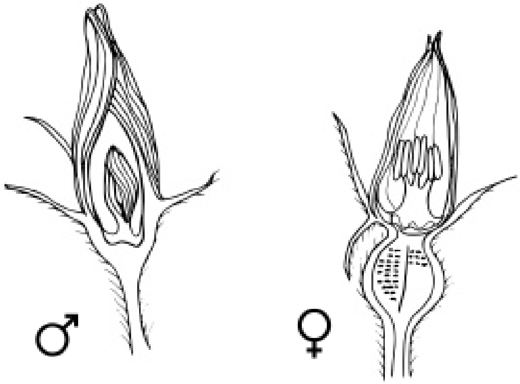
Harvest: Year round

Main varieties grown in Brazil

1st Seca, Brasileira, Delicious, Exposição, Faxon's Brazilian, Golden Hubbard, Hokkaido, Hubbard, Italiana, Japonesa, Kabocha, Libanesa, Majestade, Mammoth Gold, Menina, Mini Jack, Moranga, Paulista, Tetsukabuto Chikara

Other information

Pumpkin set fruits with an insufficient amount of pollen placed on the stigmas, but these fruits are small, lighter in weight and with fewer seeds. Introduction of honeybee colonies can ensure sufficient bee visits to maximize pollen deposition and fruit size. On average, up to 16 honeybee visits per female flower increases fruit set, but excessive visitation can lead to the removal of pollen grains already deposited on the stigmas. Insect pollinator activity before about 9 a.m. is required to set fruit, likely due to ceasing viability of the pollen grains.



Flower description

Flowers are monoecious with more male than female flowers on the same plant. Flowers are radially symmetrical with five free sepals with white hair and five yellow to orange petals that form a tubular corolla. ♀ flower with inferior ovoid unilocular ovary with short thick style and a three to five lobed stigma. ♂ flower with three filaments joining above the receptacle to form a column of stamens.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Long horned bee	*Peponapis* sp.	Solitary
Bumblebee	*Bombus* sp.	Social
Carpenter bee	*Xylocopa* sp.	Solitary
Sweat bee	*Lasioglossum* sp.	Solitary/Social
Sweat bee	*Agapostemon* sp.	Solitary
Stingless bee	*Trigona spinipes*	Eusocial
Beetle	*Diabrotica speciosa*	Solitary

Singless bees (*Trigona* sp.) visiting a male pumpkin flower

References

Amarante & Macedo (2000); Fronk & Slater (1956); Matsumoto & Yamazaki (2013); Nicodemo et al. (2009); Pfister et al. (2017); Ramos et al. (2010); Robinson & Decker-Walters (1997); Shuler et al. (2005); Walters & Taylor (2006)

Rambutan/Rambutã *Nephelium lappaceum* L.

Sapindaceae

Status: Cultivated, originates from Southeast Asia

Growing areas: PA, BA, SP

Cultivation: Trees in open plantations

Attractiveness score: 3

Pollinator dependency: High

Breeding system: Cross pollination (xenogamy) with pollen transport between hermaphrodite and male trees is common (androdioecious), self pollination through insects (geitonogamy) may be possible

Pollination requirements

Rambutan is a cross-pollinated crop and depends on insects for pollination and fruit set. The flowers are highly attractive to many insects. However, the hermaphrodite flowers are not known to shed viable pollen, and cross pollination by male plants is thought essential for efficient production.

Flowering and harvest periods

Flowering: Year round

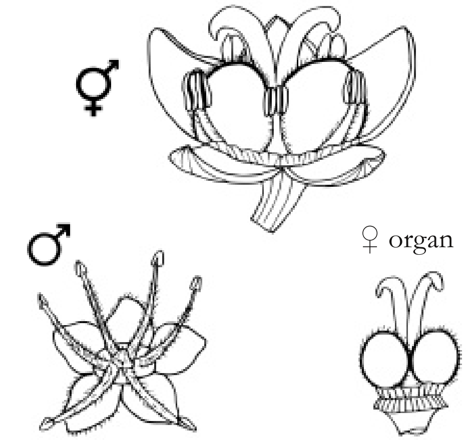
Harvest: Year round

Main varieties grown in Brazil

Jit Lee, Rongrien, R134, R156, R162, R167, R170, R191, R193

Other information

Fruit mass can significantly increase and number of mature fruits can increase nine times in trees caged with pollinators and trees with open pollination compared to trees without pollinators. As rambutan is very attractive for social bees natural habitats adjacent to the plantations should be conserved to promote for example stingless bees. Honeybees could also be managed in rambutan plantations. Honey from rambutan flowers is well known as a traditional medicine, which can accelerate healing of oral mucosa wounds. It might therefore be of interest for some beekeepers to move their hives into the plantations during blooming.



Flower description

Flowers are dioecious, either hermaphrodite or male flowers and radially symmetrical with four to seven nearly free, whitish sepals and yellowish or greenish petals that can be absent or reduced. ♀ organ with 2 carpels. ♂ organ in hermaphrodite flowers with small stamens and not opening anthers and in male flowers with well developed stamens, but not opening stigma.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Trigona* sp.	Eusocial
Stingless bee	*Scaptotrigona* sp.	Eusocial

Singless bees (*Scaptotrigona* sp.) on rambutam flowers

References

Andrade (2012); Leão (2014); Lim (1984); Muhamed & Kurien (2018); Rincón-Rabanales et al. (2015); Sacramento & Andrade (2014)

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Sesame/Gergelim *Sesamum indicum* L.

Status: Cultivated, originates from Southeast Asia

Growing areas: MA, PI, CE, RN, PB, PE, AL, SE, BA, GO, MT

Cultivation: Open fields

Attractiveness score: 4

Pollinator dependency: Modest

Plant-mating system: Self pollination (auto- and geitonogamy) and cross pollination (xenogamy)

Pollination requirements

Flowers of sesame auto pollinate around the time of anthesis, but its stigma remains receptive to receive auto or cross pollen from wind and insect pollinators, mainly bees.

Flowering and harvest periods

Flowering: January to March

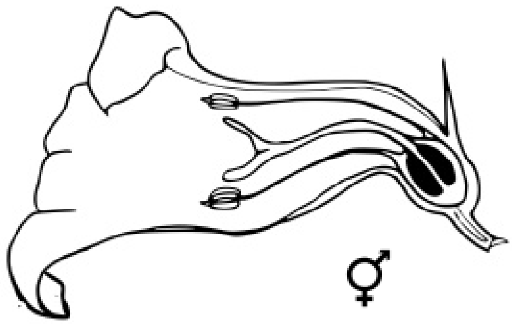
Harvest: April to May

Main varieties grown in Brazil

BRS Seda, CNPA G2, CNPA G3, CNPA G4, IAC- Ouro, IAC-China, IAC-GUATEMALA

Other information

Although cross pollination by insects reduces seed set and weight per fruit, it increases fruit set and yields per plant. Sesame can be very beneficial to rotate in a cropping system. In rotation it can break the cycle of other crop pests such as nematodes and fungi and provide attractive food resources for many pollinating insect species. It can also be grown together with crops heavily depending on pollinators. For example a favorable crop rotation could be sesame with cotton. As cotton is usually treated with insecticides, in rotation with cotton, pollinator populations might recover during the sesame rotation time.



Flower description

Flowers are hermaphrodite and bilaterally symmetrical with two bracts at the base, five petals, a calyx with oblonged lobes, five sepals, a bell–shaped white to violet corolla, with a purple spotted yellow throat. ♀ organ with a greyish hairy superior ovary and a style with a two-lobed stigma. ♂ organ with four stamens and one staminod between the two upper shorter stamens.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Trigona spinipes*	Eusocial
Carpenter bee	*Xylocopa grisescens*	Solitary
Carpenter bee	*Xylocopa carbonaria*	Solitary
Carpenter bee	*Xylocopa* conf. *suspecta*	Solitary
Carpenter bee	*Xylocopa* sp.	Solitary
Other bee	*Melissoptila uncicornis*	Solitary
Other bee	*Dicranthidium arenarium*	Solitary
Other bee	*Tetrapedia* sp.	Solitary
Other bee	*Arhysoceble* sp.	Solitary
Other bee	*Anthidium* sp.	Solitary
Leafcutter bee	*Megachile* sp.	Solitary
Sweat bee	*Lasioglossum* sp.	Solitary/Social
Wasp	*Brachygastra lecheguana*	Social
Southern green shield bug	*Nezara viridula*	Solitary

References

Andrade (2008); Andrade, et al. (2014); Ashri (2007); Porto et al. (2013); Kamel et al. (2013); Mahfouz et al. (2012); Mahmoud (2012); Napoletano (2008); Ngongolo et al. (2015); Pashte & Shylesha (2013); Porto (2013); Sarker (2004)

Soursop/Graviola *Annona muricata* L.

Annonaceae

Status: Cultivated, originates from the northern Neotropics

Growing areas: AC, AM, AP, PA, RO, RR, TO, AL, BA, CE, MA, PB, PE, PI, SE, DF, GO, MS, MT, ES, MG, RJ, SP, RN

Cultivation: Open plantations, trees in gardens

Attractiveness score: 2

Pollinator dependency: Essential

Plant-mating system: Predominantly cross pollination (xenogamy), protogynous dichogamy reduces possibility of self pollination

Pollination requirements

The flowers are naturally cross-pollinated by beetles which transport pollen from flowers in the male phase to flowers in the female phase.

Flowering and harvest periods

Flowering: September to January

Harvest: April to July

Main varieties grown in Brazil

Blanca, Boriundas, Crioula, Lisa, Morada

Other information

Beetles are attracted to the flowers for sheltering, mating and feeding on the nutritious tissues of the petals. During this activities they occasionally transport pollen and pollinate the flowers. Beetles of the genus *Cyclocephala* are the main pollinators of soursop. After leaving the flowers, female beetles often excavated holes in the soil to lay eggs. Larvae can be found between the leaf litter and the first layer of the soil. Therefore, no herbicides should be applied in soursop production to increase the availability of the natural pollinating beetles. However, due to the lack of reliable natural pollinators in agricultural settings, hand pollination is used to improve fruit set and guarantee increased production and better fruit quality than usually archived by natural pollination. Several videos on hand pollination are available for free in the internet.

Flower description

Flowers are hermaphrodite and radially symmetrical with three tiny, broad triangular, green sepals and six thick fleshy, yellowish-green petals arranged in two whorls. The outer petals are larger and pointy ovate, the inner petals are thinner, smaller and rounded. ♀ organ with one ovule in each of numerous carpels with outstanding white, narrow pistil shaped stamens, with sticky stigmas. ♂ organ with numerous shield-shaped stamens and parallel anthers opening alongside.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Beetle	*Carpophilos domidiahus*	Solitary
Beetle	*Cyclocephala gravis*	Solitary
Beetle	*Cyclocephala vestita*	Solitary
Beetle	*Cyclocephala hyrsuta*	Solitary
Beetle	*Cyclocephala picipes*	Solitary

Ants collect honeydew produced by scale insects at the flower stalk of soursop. The ants are unlikely to pollinate soursop but might protect the flower from other herbivores

References

Aguiar et al. (2000); Freitas (2012); Jalikop & Kumar (2007); Maia et al. (2012); Silva & Souza (1999); Vinay et al. (2017); Worrel et al. (1994)

Soybean/ Soja *Glycine max* (L.) Merr.

Status: Cultivated, originates from East Asia

Growing areas: MT, MS, GO, DF, RS, PR, MG, BA, TO, MA, PI, CE

Cultivation: Open fields

Attractiveness score: 4

Pollinator dependency: Modest

Plant-mating system: Most varieties are cleistogamous self-pollinating (autogamy), geitonogamy and cross pollination is possible after flower opening.

Pollination requirements

Soybean flowers usually auto pollinate before flowers completely open. Especially bees contribute to self- or cross pollination of open flowers. This increases the number of pods per plant and seed set per pod especially of flowers which failed to self-pollinate.

Flowering and harvest periods

Flowering: October to July

Harvest: January to October

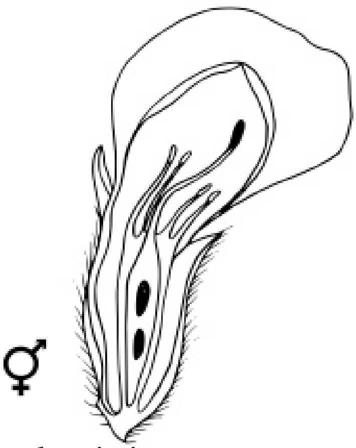
Main varieties grown in Brazil

AS 3570, As 3575, AS 3590, AS 3610, AS 3680, AS 3797, AS 3810, AS 3820, AS 3850, BRS 217 (Flora), BRS 232, BRS 252 (Serena), BRS 257, BRS 279RR, BRS 283, BRS 284, BRS 314 (Gabriela), BRS 315RR (Lívia), BRS 317, BRS 333RR, BRS 359RR, BRS 360RR, BRS 361, BRS 378RR, BRS 388RR, BRS 399RR, BRS 413RR.

List continues at p. 119

Other information

The combination of honeybee colonies and presence of wild bee species in soybean plantations increases the number of pods per plant and seeds per pod. The attractiveness of flowers for bees is highly dependent on the soybean variety. Similar as for canola, soybean is pollinated by many wild bee species but fields provide no nesting resources, farmers should provide set aside patches with flowering herbs adjacent to and within large fields.



Flower description

Flowers are hermaphrodite and laterally symmetrical with a tubular calyx of five hairy green sepals. The corolla is white or pale lilac to purple, with five petals, the posterior petal is outermost, the two lateral petals with long wings and the two anterior united petals form a keel. ♀ organ of one carpel with a superior elongated, green and unilocular ovary, the long style terminates with the stigma. ♂ organ with nine stamens fused into a tube, one posterior stamen is free.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Tetragonisca* sp.	Eusocial
Stingless bee	*Trigona fuscipennis*	Eusocial
Stingless bee	*Trigona* sp.	Eusocial
Bumblebee	*Bombus* sp.	Social
Sweat bee	*Dialictus* sp.	Solitary/Social
Sweat bee	*Halictus* sp.	Solitary/Social
Oil-collecting bee	*Centris analis*	Solitary/Social
Other bee	*Psaenythia* sp.	Solitary
Other bee	*Ancyloscelis* sp.	Solitary
Other bee	*Exomalopsis analis*	Solitary
Other bee	*Exomalopsis subtilis*	Solitary
Other bee	*Exomalopsis tomentosa*	Solitary
Other bee	*Exomalopsis ypirangensis*	Solitary
Other bee	*Florilegus* sp.	Solitary
Other bees	*Melitomella grisescens*	Solitary
Other bee	*Augochlora* sp.	Solitary
Other bees	*Augochlorella* sp.	Solitary
Other bees	*Augochloropsis* sp.	Solitary
Leafcutter bee	*Megachile* sp.	Solitary

References

Abrams et al. (1978); Barella (2009); Chiang & Kiang (1987); Chiari et al. (2005a,b); Chiari et al. (2011); Erickson (1975a,b); Erickson (1984); Erickson et al. (1978); Fávero & Couto (2000); Gazzoni (2017); Issa et al. (1984); Juliano (1977); Kettle & Taylor (1979); Koelling et al. (1981); Mason (1979); Masuda & Goldsmith (2009); Milfont (2012); Milfont et al. (2013); Ortiz-Perez et al. (2008); Pinzauti & Frediani (1980); Rust et al. (1980); Sheppard et al. (1979); Toledo et al. (2011)

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Strawberry/Morango *Fragaria* × *ananassa* Duchesne

Rosaceae

Status: Cultivated, originates from a cross of a Chilean, a European and a Northamerican species

Growing areas: BA, GO, ES, MG, RJ, SP, PR, RS, SC

Cultivation: Open and tunnel-covered fields

Attractiveness score: 4

Pollinator dependency: Modest

Plant-mating system: Self pollination (autogamy, geitogamy)

Pollination requirements

Pollination in commercial fields likely results from a combination of wind and insect pollination and both self- and cross pollination. Wind alone produces few and underdeveloped fruits. Therefore, pollination by stingless bees and honeybees is essential for both fruit production and quality.

Flowering and harvest periods

Flower: Year round

Harvest: Year round

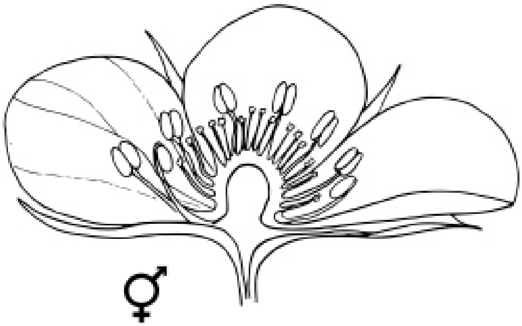
Main varieties grown in Brazil

Albion, Aromas, Camarosa, Camino Real, Cristal, Diamante, Festival, Monterrey, Oso Grande, Palomar, Portola, San Andreas, Ventana

Other information

Open pollination of flowers by stingless bees and honeybees increases fruit set, yield and quality of fruits. The combination of cross pollination and flower visits by small and large bees at the same flower results in best quality fruits with long shelf life and high market value.

In Germany it was shown that woody structures adjacent to strawberry fields enhance bee diversity and strawberry yield and fruit quality.



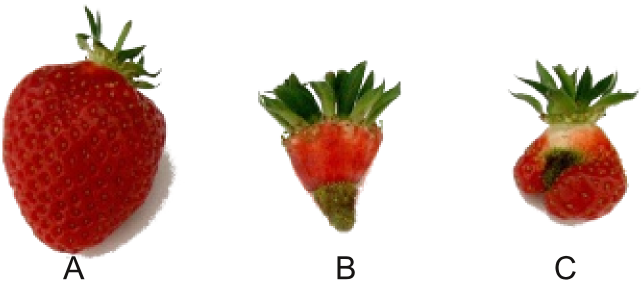
Flower description

Flowers are hermaphrodite and radially symmetrical with five sepals and five white round petals. ♀ organ with many free carpels on an elevated, cylindrical receptacle. ♂ organ with many stamens with yellow anthers.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Nannotrigona testaceicornis*	Eusocial
Stingless bee	*Paratrigona lineata*	Eusocial
Stingless bee	*Scaptotrigona depilis*	Eusocial
Stingless bee	*Tetragonisca angustula*	Eusocial
Stingless bee	*Trigona recursa*	Eusocial
Bumblebee	*Bombus* sp.	Social
Ladybird	*Coccinella septempunctata*	Solitary

Compared to the large *Apis mellifera* in the picture above the small stingless bee *Scaptotrigona depilis* only touches the flower parts close to the petals where the nectar is produced and hence unlikely pollinates the center of the flower



Strawberry fruit development after A) insect pollination, B) self pollination and C) wind pollination

References

Abrol et al. (2017); Antonelli et al. (1988a,b); Antunes et al. (2007); Chagnon (1993); Chang et al. (2001); Castle et al. (2019); Chen et al. (2011); Connor (1975); Goodman & Oldroyd (1988); Jacobs et al. (1988); Kakutani et al. (1993); Klatt et al. (2013); Malagodi-Braga & Kleinert (2004, 2007); Matsuka & Sakai (1989); McGregor (1976); Nye & Anderson (1974); Oliveira et al. (1991); Pion & Oliveira (1980); Roselino et al. (2009)

Sunflower/Girassol *Helianthus annuus* L.

Status: Cultivated, native to the Neotropics

Growing areas: AL, BA, CE, PE, PI, RN, SE, DF, GO, MS, MT, ES, MG, SP, PR, SC, PB, TO

Cultivation: Open plantations

Attractiveness score: 5

Pollinator dependency: Modest

Plant-mating system: Most varieties with self pollination (geitonogamy) and cross pollination (xenogamy)

Pollination requirements

Sunflower flowers mature from the margin to the centre of the flower head. Individual flowers are protandrous, with the male phase of pollen release preceding the female phase in which the stigma is receptive to pollination. Thus, the sticky pollen needs to be transferred between flowers within the same or of different flower heads usually by pollinators.

Flowering and harvest periods

Flowering: Year round

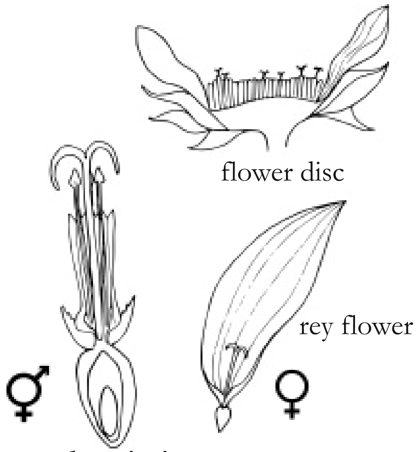
Harvest: Year round

Main varieties grown in Brazil

AG 920, AG 930, Agrobel 910, Aguará 04, Aguará 3, BRS 321, BRS 323, BRS 324, BRS 387, BRS 390, BRS H250, Cargill 11, Catissol 01, Dow M734, Dow MG2, Embrapa-122, H251, H358, H360, IAC Iarama, IAC Uruguai, Multissol, Rumbosol 90

Other information

Honeybees are the most important insect pollinators. Pollen-gathering honeybees visit only flowers in the male phase, but nectar is produced in both male and female phases. Hence, nectar-collecting bees visit all flowers of the inflorescence, pollinating those flowers that are in the female phase. The introduction of honeybee colonies into sunflower plantations increases seed set, weight, germination rate and oil content and reduces the number of mal-formed seeds.



Flower description

Flower heads are composed of up to 15000 individual hermaphrodite radially symmetrical disk flowers and mostly sterile bilaterally symmetrical yellow to reddish orange ray flowers with one long petal. Bracts surround the composed flower head. Disk flowers are small and pentamerous. ♀ organ with inferior ovary and a long, single style and a two-parted stigma. ♂ organ with five stamens, these are absent in ray flowers.

Flower visitors and pollinators

Common name	**Scientific name**	**Sociality**
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Frieseomelitta doederleini*	Eusocial
Stingless bee	*Friesomellita* sp.	Eusocial
Stingless bee	*Plebeia* aff. *flavocincta*	Eusocial
Stingless bee	*Tetragonisca angustula*	Eusocial
Stingless bee	*Trigona fuscipennis*	Eusocial
Stingless bee	*Trigona spinipes*	Eusocial
Stingless bee	*Trigona hyalinata*	Eusocial
Stingless bee	*Melipona subnitida*	Eusocial
Stingless bee	*Melipona asilvai*	Eusocial
Stingless bee	*Melipona quadrifasciata*	Eusocial
Stingless bee	*Melipona scutellaris*	Eusocial
Stingless bee	*Nannotrigona testaceicornis*	Eusocial
Stingless bee	*Geotrigona* sp.	Eusocial
Stingless bee	*Partamona helleri*	Eusocial
Stingless bee	*Paratrigona* sp.	Eusocial
Stingless bee	*Plebeia* sp.	Eusocial
Stingless bee	*Scaptotrigona* sp.	Eusocial
Stingless bee	*Tetragona* sp.	Eusocial
Stingless bee	*Tetragonisca* sp.	Eusocial
Bumblebee	*Bombus atratus*	Social
Bumblebee	*Bombus bellicosus*	Social

List continued at p. 121

References

Basualdo et al. (2000); Bhowmik & Bhadra (2015); Calmasur &, Ozbek (1999); Carvalheiro et al. (2011); Castro & Leite (2018); Chambó et al. (2011); Cockerell (1914); Cruz & Freitas (2013); DeGrandi-Hoffman & Chambers (2006); DeGrandi-Hoffman & Martin (1993); DeGrandi-Hoffman & Watkins (2000); Delaude et al. (1979); Fell (1986); Free (1964); Furgala et al. (1979); Greenleaf & Kremen (2006); Krause & Wilson (1981); Langridge & Goodman (1981); Machado & Carvalho (2006)

List continues at p. 119

Sweet pepper/Pimentão *Capsicum annuum* L.

Status: Cultivated, originates from the northern Neotropics

Growing areas: All states of Brazil

Cultivation: Open and tunnelled plantations

Attractiveness score: 4

Pollinator dependency: Little

Plant-mating system: Self pollination (autogamy and geitonogamy), cross pollination (xenogamy) can also occur

Pollination requirements

Sweet pepper flowers are mostly autogamous self-pollinated. Cross pollination is mostly conducted by bees capable of buzz pollination. The resulting fruit quality is higher than of self-pollinated fruits. The flower of the sweet pepper is best pollinated in the morning of the day when the flower opens, when the pollen is released and the stigma becomes receptive.

Flowering and harvest periods

Flowering: Year round

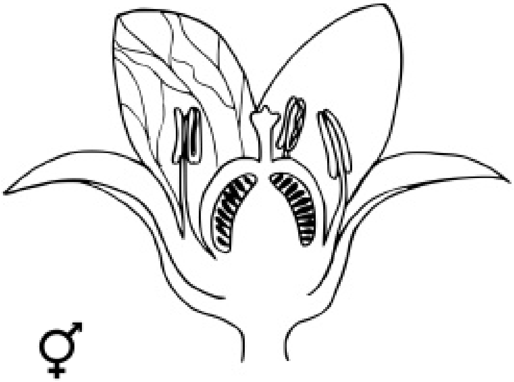
Harvest: Year round

Main varieties grown in Brazil

Agronômico 10G, All Big, Amarelo SF 134, Andes Kobayashi, Ário, Athenas, Atlantis, Avelar, BEti R, Bruna R, Bruno, Camaro, Canarinho, Cascadura Ikeda, Cascadura Marina, Cida R, Commandant, Conrado, Dagma, Dahra R, Dahra RX, Derick, Elisa, Esplendor, Êxito, Fortuna Super, Gigante Ikeda, Green Belt Kobayashi, Hebron, Heloísa, Isabela, Itamara, Itapuã, Konan, Laser, Lotus, Magali, Magali R, Magda, Magna Super, Magnata, Marha R, Marli R, Marta, Melina, Mirella, Nádia, Paloma, Priscila, Proveito, Quadrado Vermelho, Rubi Giant, Rubia R, Satrapo-Sais, Stela, Sucesso, Taurus, Triunfo, Yolo Wonder

Other information

Pollination by bees increases fruit size, weight, number of seeds and reduces fruit malformation in sweet pepper.



Flower description

Flowers are hermaphrodite and radially symmetrical with five white to pale lilac, triangular, slightly cupped petals. ♀ organ with two carpels fused into a superior ovary. ♂ organ with five bluish stamens fused to the petals at the base.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Melipona subnitida*	Eusocial
Stingless bee	*Melipona scutellaris*	Eusocial
Stingless bee	*Nannotrigona testaceicornis*	Eusocial
Stingless bee	*Tetragonisca angustula*	Eusocial
Stingless bee	*Trigona recursa*	Eusocial
Stingless bee	*Trigona spinipes*	Eusocial
Stingless bee	*Paratrigona lineta*	Eusocial
Bumblebee	*Bombus atratus*	Social
Sweat bee	*Augochlora* cf. *morrae*	Solitary/Social
Sweat bee	*Augochlora morrae*	Solitary/Social
Sweat bee	*Augochlora thalia*	Solitary/Social
Sweat bee	*Augochlora* sp.	Solitary/Social
Sweat bee	*Augochlorella acarinata*	Solitary/Social
Sweat bee	*Augochlorella theia*	Solitary/Social
Sweat bee	*Augochloropsis aurifluens*	Solitary/Social
Sweat bee	*Augochloropsis cleopatra*	Solitary/Social
Sweat bee	*Augochloropsis caerulior*	Solitary/Social
Sweat bee	*Augochloropsis cupreola*	Solitary/Social
Sweat bee	*Augochloropsis heterochroa*	Solitary/Social
Sweat bee	*Augochloropsis laeta*	Solitary/Social
Sweat bee	*Augochloropsis wallacei*	Solitary/Social
Sweat bee	*Pereirapis rizophila*	Solitary/Social
Sweat bee	*Halictus lanei*	Solitary/Social
Sweat bee	*Lasioglossum picadense*	Solitary/Social
Sweat bee	*Lasioglossum ypirangense*	Solitary/Social

List continues at p. 121

References

Cruz et al. (2004, 2005); Dag & Kammer (2001); Dag et al. (2007); De Ruijter et al (1991); Faria Jr et al. (2008); Reifschneider (2000); Jarlan et al. (1997); Pereira et al. (2015); Raw (2000) Roselino (2005); Roselino et al. (2010); Silva et al. (2005)

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Tomato/Tomate *Solanum lycopersicum* L.

Status: Cultivated, originates from the northern Neotropics

Growing areas: All states of Brazil

Cultivation: Open fields and tunnels

Attractiveness score: 3

Pollinator dependency: Little

Plant-mating system: Self pollination (autogamy, geitonogamy) and cross pollination (xenogamy) can also occurs

Pollination requirements

Pollen grain release of the anthers and transfer to the stigma is strongly facilitated through wind, rain and other impacts vibrating the flower. Especially buzz pollination by specific bees of the genera *Melipona*, *Xylocopa* and *Bombus* increases fruit set, yield and quality.

Flowering and harvest periods

Flowering: Year round

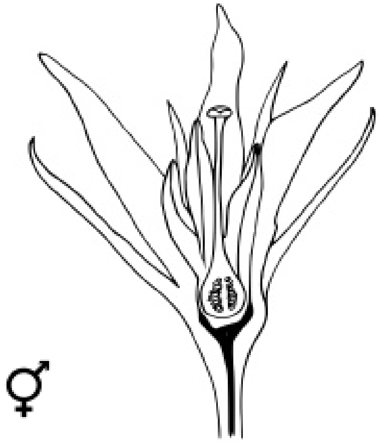
Harvest: Year round

Main varieties grown in Brazil

Aliança, Andrea, Andrea Vistory, BRS Kiara, BRS Nagai, BRS Portinar, Carina, Débora Max, Débora Plus, Débora Victory, Delta, Gisele, Giuliana, Grande HT, IPA 6, Ivete, Júpiter, Kombat, Lumi, Pleno F1, Red Petit, Red sugar, Renata, Samambaia, San Vito, Santa Clara, Santa Clara VF 5600, Santa Cruz Kada, Sheila, Sindy, Sweet gold, Tyler, Tyna, Zamir

Other information

Wild bees that buzz pollinate increase the pollen load on the stigma and consequently fruit production and quality. Some bees that do not buzz-pollinate also contribute to tomato pollination by drumming the tips of the poricidal anthers with their forelegs or milking the anthers to release pollen. In open cultivation, wind shaking the flowers also contributes to self pollination.



Flower description

Flowers are hermaphrodite and radially symmetrical with five to ten green sepals and five bright yellow triangular, slightly cupped petals. ♀ organ with two carpels fused into a superior ovary with a green style and stigma. ♂ organ with five yellow stamens fused into a tube.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Paratrigona lineata*	Eusocial
Stingless bee	*Melipona quinquefasciata*	Eusocial
Stingless bee	*Trigona spinipes*	Eusocial
Stingless bee	*Frieseomelitta* sp.	Eusocial
Stingless bee	*Frieseomelita flavicornis*	Eusocial
Stingless bee	*Melipona quadrifasciata*	Eusocial
Stingless bee	*Geotrigona subterranea*	Eusocial
Stingless bee	*Tetragonisca angustula*	Eusocial
Stingless bee	*Tetragona* sp.	Eusocial
Stingless bee	*Plebeia* sp.	Eusocial
Stingless bee	*Frieseomelitta* sp.	Eusocial
Bumblebee	*Bombus morio*	Social
Bumblebee	*Bombus pauloensis*	Social
Bumblebee	*Bombus* sp.	Social
Carpenter bee	*Xylocopa suspecta*	Solitary
Carpenter bee	*Xylocopa frontalis*	Solitary
Carpenter bee	*Xylocopa* sp.	Solitary
Oil-collecting bee	*Centris aenea*	Solitary
Oil-collecting bee	*Centris tarsata*	Solitary
Oil-collecting bee	*Centris tarsata*	Solitary
Oil-collecting bee	*Centris fuscata*	Solitary
Oil-collecting bee	*Centris varia*	Solitary

List continues at p. 122

References

Banda & Paxton (1991); Bezerra & Machado (2003); Bin & Soressi (1973); Bohart & Todd (1961); Cauich et al. (2004); Cribb (1990); Del Sarto et al. (2004,2005); Deprá et al. (2014); Eijnde & Ruijter (1989); Franceschinelli et al. (2013); Gaglianone & Campos (2015); Higo et al. (2004); Sabara et al. (2004); Sabara & Winston (2003); Santos et al. (2009, 2014); Silva-Neto et al. (2013, 2017); Vinícius-Silva et al. (2017)

Watermelon/Melancia *Citrullus lanatus* (Thunb.) Matsum. & Nakai

Status: Cultivated, originates from West Africa

Growing areas: AC, AM, BA, CE, MA, PB, PE, RJ, SC, GO, RS, SP, PI, RN, TO, MG, ES, PR

Cultivation: Creeping vine-like plants in open plantations

Attractiveness score: 4

Pollinator dependency: Essential

Plant-mating system: Self pollination (geitonogamy) and cross pollination (xenogamy)

Pollination requirements

Watermelon flowers, including seedless varieties, need pollen transfer from male to female flowers to set fruits. Plant individuals are mostly monoecious, sometimes dioecious or andromonoecious but always require insects to transfer the sticky pollen. Flowers are most receptive in the morning hours and provide both nectar and pollen to insect pollinators, in particular to bees.

Flowering and harvest periods

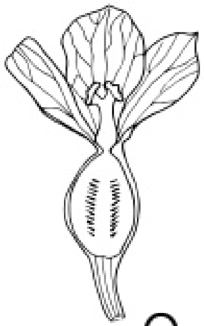
Flower & Harvest: Year round

Main varieties grown in Brazil

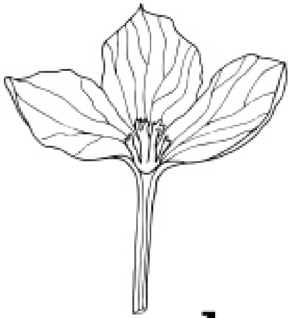
Blackstone, Charleston Gray, Companion **List continues at p. 119**

Other information

A minimum number of viable pollen grains is needed to set a fruit, which usually, results from multiple pollinator visits. Fruit set in seeded watermelon can be maximized with more than 1,000 pollen grains per flower, which is accomplished by 6 to 8 honeybee or one bumblebee visitation. Pistillate flowers of seedless varieties need more than the double number of visits to set fruit. A unique situation exists for pollination in seedless (triploid) watermelons. They are not parthenocarpic and require a pollination stimulus for fruit set. Since triploid watermelon produce mostly nonviable pollen, the pollination stimulus must be provided by viable pollen grains from seeded diploid pollinizers that are planted in close proximity.



♀



♂

Flower description

Plants are usually monoecious, sometimes dioecious or andromonoecious, with radially symmetrical male and female flowers. The calyx is bell shaped with five lobes and a light yellow five-parted tubular corolla. ♀ flower with inferior ovoid unilocular ovary, with a short style and three stigmas. ♂ flower with three nearly free stamens and a gland resembling an ovary.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Stingless bee	*Trigona fulviventris*	Eusocial
Stingless bee	*Trigona spinipes*	Eusocial
Stingless bee	*Plebeia* sp.	Eusocial
Stingless bee	*Scaptotrigona* sp.	Eusocial
Stingless bee	*Melipona* sp.	Eusocial
Bumblebee	*Bombus* sp.	Social
Cucumber bee	*Peponapis* sp.	Solitary
Long-horned bee	*Melissodes* sp.	Solitary
Carder bee	*Hypanthidium* sp.	Solitary
Carpenter bee	*Xylocopa* sp.	Solitary
Small carpenter bee	*Ceratina* sp.	Solitary
Sweat bee	*Lasioglossum* sp.	Solitary/Social
Sweat bee	*Agapostemon* sp.	Solitary
Sweat bee	*Augochloropsis* sp.	Solitary/Social
Sweat bee	*Halictus* sp.	Solitary/Social
Sweat bee	*Augochlorella* sp.	Solitary/Social
Sweat bee	*Augochlora* sp.	Solitary/Social
Masked bee	*Hylaeus* sp.	Solitary
Leafcutter bee	*Megachile* sp.	Solitary
Other bee	*Exomalopsis* sp.	Solitary
Other bee	*Heriades* sp.	Solitary

References

Adlerz (1966); Alencar (2013); Azo'o et al. (2010); Bomfim, et al. (2015); Brewer (1974); Bussman et al. (2003); Goff (1937); Kaziev & Seidova (1965); Kremen et al. (2004); Kremen et al. (2002); Meléndez-Ramirez et al. (2002); Mohamed & El-Hafez (1974); Njoroge et al. (2004, 2010); Pinkus-Rendon et al. (2005); Pisanty (2014); Smith et al. (2013); Spangler & Moffett (1979); Stanghellini et al. (1998a,b & 2002a,b); Walters (2005); Walters & Schultheis (2009); Wilson et al. (2016); Winfree et al. (2008)

Zucchini/Abobrinha *Cucurbita pepo* L.

Status: Cultivated, originates from the Neotropics

Growing areas: TO, BA, PB, DF, GO, MS, MT, MG, RJ, SP, PR, SC, ES

Cultivation: Open plantations

Attractiveness score: 4

Pollinator dependency: Essential

Plant-mating system: Self pollination (geitonogamy) and cross pollination (xenogamy)

Pollination requirements

Although zucchini/squash plants are self-compatible, they need pollinators to set fruits, because they have separate staminate (male) and pistillate (female) flowers at the same plant and the pollen grains are too large and sticky to be carried by wind. Pollination is most successful in the morning and requires insect activity of for example honeybees to transfer pollen between flowers within one or different plant individuals.

Flowering and harvest periods

Flowering period: August to May

Harvest period: 30 to 45 after pollination

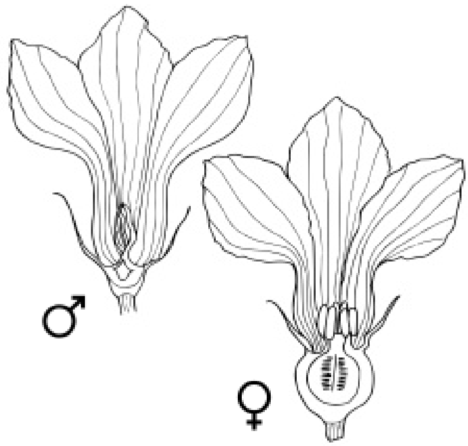
Main varieties grown in Brazil

Caserta SH-202, Caserta CAC, Caserta BR, Clarinda AG-135, Clarita, Cocozelle

Other information

Fruit set and seed production are strongly influenced by bee visitation. The percentage of fruit set, fruit weight, shape, and seed production are all affected by the number of bee visits and type of bee species. A minimum number of viable pollen grains (optimum 1,200 pollen grains per flower), which usually requires multiple pollinator visits (optimum e.g. 12 honeybee visits) is needed for fruit set.

The cucumber bee *Peponapis* sp. is specialized on zucchini and cucumber and other plants of this plant family. It is a ground-nesting bee and can be promoted by open, sandy grounds without herbicide applications adjacent or in the plantations.



Flower description

Flowers are separated in male and female flowers and radially symmetrical with five yellow petals. Male flowers are smaller, with a longer pedicel. ♀ flower with two to three lobed stigma on a short style and an inferior ellipsoid ovary. ♂ flower with five stamens (tubular stamens that join from the fillet, forming a column) and no ovary.

Flower visitors and pollinators

Common name	Scientific name	Sociality
Honeybee	*Apis mellifera*	Eusocial
Bumblebee	*Bombus morio*	Social
Bumblebee	*Bombus* sp.	Social
Bumblebee	*Bombus atratus*	Social
Stingless bee	*Frieseomelitta* sp.	Eusocial
Stingless bee	*Geotrigona mombuca*	Eusocial
Stingless bee	*Melipona seminigra*	Eusocial
Stingless bee	*Melipona quadrifasciata*	Eusocial
Stingless bee	*Melipona quinquefasciata*	Eusocial
Stingless bee	*Partamona combinata*	Eusocial
Stingless bee	*Paratrigona lineata*	Eusocial
Stingless bee	*Trigona hyalinata*	Eusocial
Stingless bee	*Trigona spinipes*	Eusocial
Stingless bee	*Trigona fulviventris*	Eusocial
Stingless bee	*Tetragona* sp.	Eusocial
Stingless bee	*Schwarziana mourei*	Eusocial
Stingless bee	*Trigona* sp.	Eusocial
Stingless bee	*Plebeia* sp.	Eusocial
Cucumber bee	*Peponapis* sp.	Solitary
Carpenter bee	*Xylocopa* sp.	Solitary
Small carpenter bee	*Ceratina* sp.	Solitary
Orchid bee	*Eulaema cingulata*	Solitary
Sweat bee	*Agapostemon semimelleus*	Solitary
Sweat bee	*Augochloropsis cupreola*	Solitary/Social
Sweat bee	*Halictus* sp.	Solitary/Social
Sweat bee	*Lasioglossum* sp.	Solitary/Social

List continues at p. 122

References

Artz & Nault (2011); Baptista (2016); Delaplane et al. (2000); Enriquez et al. (2015); Fronk & Slater (1956); Grewal & Sidhu (1978); Julier & Roulston (2009); Krug et al. (2010); Kubisova (1974); Nepi & Pacini (1993); Petersen et al. (2014); Petersen et al. (2013); Phillips (2013); Phillips & Gardiner (2015); Tepedino (1981); Torezani (2015) Vidal et al. (2010); Walters & Taylor (2006)

Comprehensive list of crops cultivated in Brazil with recommendations for a potential pollinator-safe application of pesticides

This list comprises the crops cultivated in Brazil as listed by the FAO for the year 2017, complemented by additional crops we identified to be important for some regions in Brazil but not listed by the FAO. We refer to crops used at least partly for human consumption.
Note: As a general best practice recommendation to protect pollinators, all crops with an attractiveness score of 2 or > 2 should not be treated during flowering with pesticides. If there are no options to do the application before or after flowering, we recommend pesticide applications only with products explicitly identified as harmless for pollinators. We highlight these crops in bold.

Table 4: Overview of Brazilian crops with their bee attractiveness and their dependency on animal pollinators.
Attractiveness score (1- low or no attractiveness for animal pollinators to 5- highly attractive for animal pollinators, NA = degree of attractiveness unknown). Pollinator dependency categories (essential, high, modest, little, no poll = no insect pollinators needed, seeds = pollination only for seed production, NA). More information on pollinator attractiveness and pollination dependency are available at page 12 in the explanations of this guide. Scores and categories are used from Klein et al. (2007), other scientific papers and our expert knowledge.

Crop	**Latin name**	**Attract.**	**Poll. Dep.**
Açaí palm/Açaí	*Euterpe oleraceae*	**5**	High
Acerola/Acerola	*Malpighia emarginata*	**3**	High
Agave/Agave	*Agave* sp.	**3**	Seeds
Alfalfa/Alfafa	*Medicago sativa*	**4**	High
Almond/Amêndoa	*Prunus dulcis*	**4**	High
Anise/Erva doce, Anis	*Pimpinella anisum*	**3**	Modest
Anatto/Urucum	*Bixa orellana*	**4**	High
Apple/Maçã	*Malus domestica*	**4**	High
Apricot/Damasco	*Persea armeniaca*	**4**	High
Artichoke/Alcachofra	*Cynara cardunculus*	**5**	Seeds
Asparagus/Aspargo	*Asparagus officinalis*	**2**	Seeds
Avocado/Abacate	*Persea americana*	**4**	High
Bambara bean/Amendoim do Bambara	*Vigna subterranea*	**2**	Little
Banana, Plantain/Banana, B.-da-terra	*Musa* spp.	**2**	No poll
Barley/Cevada	*Hordeum vulgare*	1	No poll
Blueberry/Mirtilo	*Vaccinium* sp.	**4**	High
Brazilian grapetree/Jabuticaba	*Plinia cauliflora*	**3**	Little
Brazil nut/Castanha do Pará	*Bertholletia excelsa*	**4**	Essential
Broad bean/Fava	*Vicia faba*	**4**	Modest
Buckwheat/Trigo-sarraceno	*Fagopyrum esculentum*	**5**	High
Cabbage, Cauliflower etc. /Repolho, Couve-flor etc.	*Brassica oleraceae*	**4**	Seeds/modest
Canola/Canola	*Brassica napus*	**5**	Modest
Cardamom/Cardamono	*Elettaria cardamomum*	**4**	High
Carob/Alfarrobeira	*Ceratonia siliqua*	**3**	Modest
Carrot/Cenoura	*Daucus carota sativus*	**5**	Seeds/ high

Crop	Latin name	Attract.	Poll. Dep.
Cashew/Caju	*Anacardium occidentale*	**4**	High
Cassava/Mandioca	*Manihot esculenta*	**2**	Seeds/little
Castor bean/Mamona	*Ricinus communis*	**2**	Modest
Cherry (sweet/sour)/Cereja	*Prunus avium*	**5**	High
Chestnut/Castanha portuguesa	*Castanea sativa*	**4**	Modest
Chick pea/Grão-de-bico	*Cicer arietinum*	**3**	Little
Chicory/Chicória	*Cichorium intybus*	**4**	Little/seeds
Chilli pepper/Pimenta	*Capsicum annuum*	**3**	Little
Cinnamon/Canela	*Cinnamomum verum*	**2**	NA
Citrus Citrus, Lime, Clementine, Grapefuit, Mandarine, Orange, Tangerine/Frutas cítricas	*Citrus* spp.	**4**	Little
Clover (red)/Trevo	*Trifolium pratensis*	**4**	High
Cocoa/Cacau	*Theobroma cacao*	**4**	Essential
Coconut/Coco	*Cocos nucifera*	**4**	Modest
Coffee/Café	*Coffea arabica*	**4**	Modest
Common bean/Feijão	*Phaseolus vulgaris*	**4**	Little
Cotton/Algodão	*Gossypium hirsutum*	**4**	Modest
Coriander/Coentro	*Coriandrum sativum*	**4**	Seeds/High
Cowpea/Feijão-caupi	*Vigna unguiculata*	**3**	Little
Cranberry/Cranberry	*Vaccinium macrocarpon*	**4**	High
Cucumber/Pepino	*Cucumis sativus*	**4**	High
Cupuassu/Cupuaçu	*Theobroma grandiflorum*	**2**	High
Currant/Groselha, Cassis	*Ribes nigrum, R. rubrum*	**3**	Modest
Date palm/Tamareira	*Phoenix dactylifera*	**2**	Little
Eggplant/Beringela	*Solanum melongena*	**3**	Modest
Fennel/Erva-doce, Funcho	*Foeniculum vulgare*	**4**	High
Fig/Figo	*Ficus carica*	**2**	Essential
Flax seeds/Linho, linhaça	*Linum usitatissimum*	**3**	Little
Garlic/Alho	*Allium sativum*	**3**	Seeds/little
Ginger/Gengibre	*Zingiber officinale*	NA	NA
Gooseberry/Groselha	*Ribes uva-crispa*	**3**	Modest
Grape/Uva	*Vitis vinifera*	**2**	No poll
Groundnut/Amendoim	*Arachis hypogea*	**2**	Little
Gourd/Cabaça	*Curcubita* spp.	**4**	Essential
Guava/Goiaba	*Psidium guajava*	**3**	Modest
Hazelnut/Avelã	*Coryllus avellana*	**4**	No poll
Hop/Lúpulo	*Humulus lupulus*	**2**	No poll
Karite nuts (sheanuts)/Carité	*Vitellaria paradoxa*	**3**	Modest
Kiwi/Kiwi	*Actinidia deliciosa*	**4**	Essential
Kola/Noz-de-cola	*Cola* spp.	NA	NA
Lentil/Lentilha	*Lens esculenta*	**3**	No poll
Lettuce/Alface	*Lactuca sativa*	**2**	Seeds
Linseed/Linhaça	*Linum usitatissimum*	**3**	Little
Lychee/Lichia	*Litchi chinensis*	**4**	Little
Lupin/Tremoço	*Lupinus alba*	**5**	Little
Maize/Milho	*Zea mays*	**2**	No poll
Mango/Manga	*Mangifera indica*	**4**	High
Mangosteen/Mangostim, Mangostão	*Garcinia mangostana*	NA	No poll
Maté/Mate, Erva-mate	*Ilex paraguariensis*	**3**	NA seeds/high
Melon/Melão	*Cucumis melo*	**4**	Essential
Millet/Painço	*Panicum miliaceum*	1	No poll
Mushroom/Cogumelo	*Agaricus bisporus, A. brasiliensis, Pleurotus ostreatus and others*	0	No poll
Mustard/Mostarda	*Sinapis arvensis*	**5**	High
Nutmeg/Noz-moscada	*Myristica fragrans*	**4**	High
Nectarine/Nectarine	*Prunus persica var. nucipersica*	**4**	High
Oil palm/Dendê	*Elaeis guineensis*	**4**	High
Okra/Quiabo	*Abelmoschus esculentus*	**3**	Modest

Crop	Latin name	Attract.	Poll. Dep.
Olive/Oliveira	*Olea europaea*	**2**	Little
Onion/Cebola	*Allium cepa*	**4**	Seeds/high
Papaya/Mamão	*Carica papaya*	**4**	Little
Passion fruit/Maracujá	*Passiflora edulis*	**4**	Essential
Peach/Pêssego	*Prunus persica*	**5**	High
Pepper (sweet)/Pimentão	*Capsicum annuum*	**4**	Little
Pear/Pera	*Pyrus communis*	**3**	High
Pea/Ervilha	*Pisum sativum, P. arvense*	**2**	No poll
Peppermint/Hortelã-pimenta	*Mentha × piperita*	**5**	High
Persimmon/Caqui	*Diospyros kaki*	**3**	Little
Pigeon pea/Feijão guandu	*Cajanus cajan*	**3**	Little
Pineapple/Abacaxi	*Ananas comosus*	**2**	Seeds
Pistachio/Pistache	*Pistacia vera*	**2**	No poll
Plum/Ameixa	*Prunus domestica*	**4**	High
Potato/Batata	*Solanum tuberosum*	**2**	Seeds
Sloe/Abrunho	*Prunus spinosa*	**5**	High
Pumpkin/Abóbora	*Cucurbita maxima*	**4**	Essential
Quince/Marmelo	*Cydonia oblonga*	**4**	Modest
Quinoa/Quinoa	*Chenopodium quinoa*	**3**	Modest
Rambutan/Rambutã	*Nephelium lappaceum*	**3**	High
Raspberry/Framboesa	*Rubus idaeus*	**4**	High
Rice/Arroz	*Oryza sativa*	1	No poll
Rye/Centeio	*Secale cereale*	1	No poll
Safflower/Açafroa	*Carthamus tinctorius*	**4**	Little
Sesame/Gergelim	*Sesamum indicum*	**4**	Modest
Sorghum/Sorgo	*Sorghum guineense, S. vulgare, S. dura*	**2**	No poll
Soursop/Graviola	*Annona muricata*	**2**	Essential
Soybean/Soja	*Glycine max*	**4**	Modest
Spinach/Espinafre	*Spinacia oleracea*	**2**	No Poll
Strawberry/Morango	*Fragaria × ananassa*	**4**	Modest
String bean/Feijão-da-espanha	*Phaseolus coccineus*	**4**	High
Sugar beet/Beterraba	*Beta vulgaris*	1	No poll
Sugar cane/Cana de açúcar	*Saccharum officinarum*	1	No poll
Sunflower/Girassol	*Helianthus annuus*	**5**	Modest
Sweet potato/Batata doce	*Ipomoea batatas*	**4**	Seeds
Squash/Abóbora	*Cucubita mixta, C. moschata*	**4**	Essential
Tarot/Taro, Inhame	*Colocasia esculenta*	**2**	Seeds
Tea/Chá	*Camellia sinesis*	**2**	Little
Tomato/Tomate	*Solanum lycopersicum*	**3**	Modest
Triticale/Triticale	*×Triticosecale*	1	No poll
Truffle/Trufas	*Different species of fungy*	1	No poll
Vanilla/Baunilha	*Vanilla planifolia, V. pompona*	**3**	Essential
Vetche/Ervilhaca	*Vicia* spp.,	**4**	High
Walnut/Noz comum	*Junglans regia*	**4**	No poll
Watermelon/Melancia	*Citrullus lanatus*	**4**	Essential
Wheat/Trigo	*Triticum aestivum*	1	No poll
Yautia/Taioba	*Xanthosoma sagittifolium*	NA	Seeds
Zucchini/Abobrinha	*Cucurbita pepo*	**4**	Essential

Managing pollinators – description of pollinators that can be managed to enhance or stabilize crop production

Western honeybee *Apis mellifera*

Honeybee on anatto flower

Honeybee on acerola flower

Honeybee on cashew flower

Honeybee on coffe flower

Sociality: Eusocial

Colony size: 10,000 to 80,000 workers

Size: 12 to 13mm

Food resources: Pollen and nectar from many wild and cultivated plants.

Nesting location: Large hollow spaces, open spaces, tree branches/trunks, abandoned ant and termite nests but mainly kept by humans (beekeepers) in artificial hives.

Further resources: Plant resin, honeydew, water

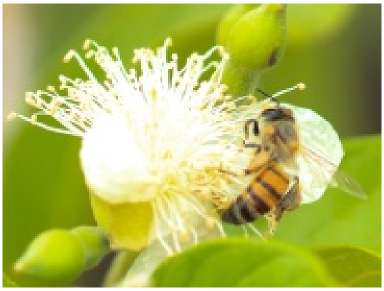
Honeybees as crop pollinators: Honeybees are known to visit all crops listed in this pollination guide, except cocoa but although they visit açaí palm, acerola, annato, brazil nut, tomato, passionfruit and sweet pepper, they are usually not pollinating these crops as the flower morphologies do not fit to the bee morphology or because buzz pollination is required and honeybees cannot buzz pollinate.

Natural occurrence and management for crop pollination

The Western honeybee (*Apis mellifera*) was introduced to North America around 1600, from there the species spread across both American continents by establishing feral populations. In 1957 the so called African honeybee (*Apis mellifera scutellata*) was introduced to Brazil. Some swarms escaped and established populations throughout all subtropical and tropical parts of the Americas (Winston et al. 1981, Whitfield et al. 2006). Feral honeybees in Brazil are currently mostly Africanized (a hybrid of *A. m. scutellata* and European races of *A. mellifera*) honeybees. They establish colonies in many rain sheltered places such as hollow tree branches or trunks, roofs of buildings or abandoned ant and termite nests.

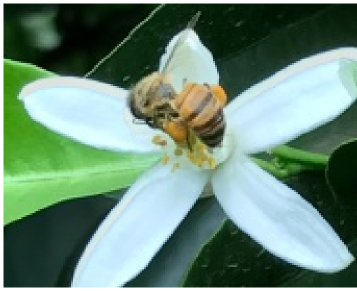
Roubik (1995) mentioned that stocking densities in fields with watermelon or coconut in tropical southeast Asia are 4-8 colonies per ha. Delaplane et al. (2000) suggest different stocking rates for different crops in the US. Deciding about the best stocking rate, when to place and for how long is complicated and also depends on the availability of wild bees around the crop fields. It is also important that if pesticides are applied, honeybees honeybees should not be placed in crop fields during their applications. Exemptions might be products specifically labelled as non-toxic to bees, allowing bee-safe application.

The management of honeybees in hives is an elegant way to enhance pollination of many crop species. As honeybee keeping is time consuming and even more complex in tropical than in temperate regions, we advise farmers to read specific literature about honeybee crop pollination management, join local beekeeping courses or to work with experienced beekeepers to use honeybees in their crop fields. As we can not address this complex topic within the limited space of our guide, we suggest that recommendations are needed in a specific guide on honeybee management for Brazil, such as "Polinizadores e Pesticidas: princípios e manejo para os agroecossistemas brasileiros" by Freitas & Pinheiro (2012).



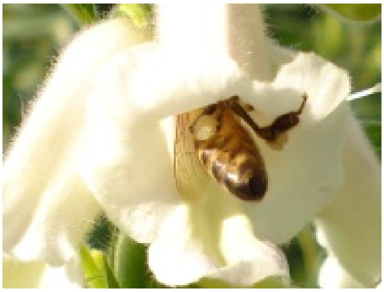
Honeybee on a guava flower

Honeybee on a melon flower



Honeybee on an orange flower

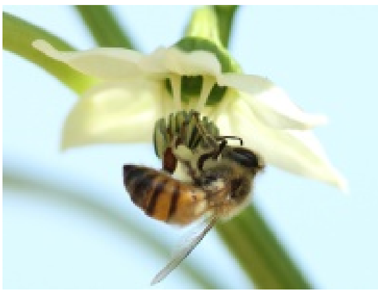
Honeybee on canola flowers



Honeybee on a sesame flower

Honeybee on a soybean flower

Honeybee on sunflower flowers



Honeybee on a sweet pepper flower

Honeybee on a watermelon flower

Bumblebees *Bombus* spp.

Sociality: Social

Colony size: up to 500 workers

Size: 11 to 17mm

Food resources: Pollen, nectar and honeydew of plants

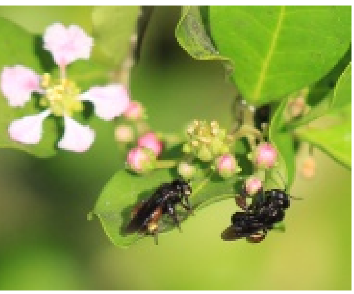
Nesting location: Beneath leaves and debris, burrows in the ground

Further resources: Water, leaf litter

Bumblebees as crop pollinators: We identified from the scientific literataure five bumblebee species as crop pollinators in Brazil (*Bombus atratus* (syn.: *B. pauloensis*), *B. bellicosus*, *B. brevivillus*, *B. morio*, *B. trasversalis*). Crops visited by bumblebees from our guide are avocado, apple, brazil nut, canola, coffee, common bean, cotton, cowpea, melon, passion fruit, peach, pear, plum, pumpkin, strawberry, sunflower, sweet pepper, tomato, watermelon, and zucchini. The authors of this guide also observed bumblebees on persimmon and sesame. In general, bumblebee species are primarily found in higher altitutes and more temperate regions of Brazil.

Natural occurrence and management:

Bumblebee nests can be found in different locations and structures above and below the ground. In Europe *Bombus terrestris* is frequently breed for crop pollination. The biology and the behaviour of this European bumblebee is well known. This is different in Brazil and the biology of Brazilian bumblebees is different to the managed bumblebees in Europe and in the US. Hence, we can currently not recommend breeding bumblebees for crop pollination management. For example, *Bombus atratus* can have multiple queens laying eggs or a single queen per nesting cycle. Multiple queens lead to aggressive behaviour, which is not the case for the species bread in Europe. *B. atratus* nests can pertain longer times than these of European bumblebees, which should be an advantage to use colonies kept in artificial nests as crop pollinators. Again, bumblebee breeding is only it is infancy in South America, for example see Almanza Fandiño (2007). Instead of keeping bumblebee colonies in artifical nests, we encourage farmers to observe which wild and crop flowers are visited by bumblebees near their farms and to promote those flowers to increase the population size and numbers of wild bumblebees. Using for example the free mobile phone App iNaturalist (https://inaturalist.org), farmers can identify the bumblebees and other bees and the flowers they are visiting. With this information, they can find information on the biology and ecology of the bees and the plants to gather information how to promote bumblebees on their land.



Trigona spinipes on acerola flowers

Stingless bees Meliponini

Sociality: Eusocial

Colony size: 100 to 100.000 workers

Size: 2.6 to 14mm

Food resources: Pollen, nectar, fruit juice, organic liquids

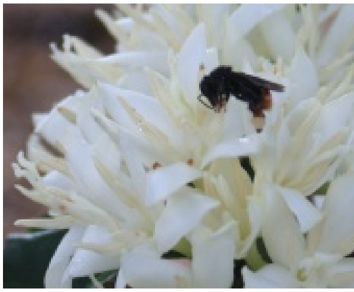
Nesting location: Large holow spaces, in the open, tree trunks, tree branches, hollows in the ground, termite nests, artificial hives

Further resources: Resin, seeds, petals, plant fibers, water

Stingless bees as crop pollinators: More than 200 species of stingless bees are known from Brazil with 89 endemic species (Pedro et al. 2014). We identified 49 species of stingless bees visiting the crop species in our guide and we could identify stingless bee flower visits for almost all the crops listed in this guide, except for okra, pear and soursop. The often small-sized stingless bees also visit large crop flowers such as flowers of brazil nut or passion fruit but they provide limited pollination as their body size does not match the flower size of these crops. The most common stingless bee species visiting crop flowers is *Trigona spinipes* but *Melipona subnitida*, *Melipona quadrifasciata*, *Nannotrigona testaceicornis*, *Paratrigona lineata* and *Tetragonisca angustula* visit also several different crop species. Stingless bees can buzz pollinate flowers and are therefore important pollinators for crop plants requiring buzz pollination. Such plants belong for example to the plant family Solanaceae including crops like tomato or sweet pepper. As stingless bees are diverse and abundant and occur throughout Brazil they are important crop pollinators and should be protected and promoted by farmers. Stingless bees have reduced stingers and can not sting humans but defend their nests with biting, which can be uncomfortable. Futhermore, some stingless bees have very small colonies, some do not survive in artifical hives, and some collect large amount of plant resin making nest boxes sticky. Finally, stingless bees are also nectar thieves and are known to sometimes destroy crop flowers (Gutierrez-Chacón et al. 2018). Because of these reasons only few species are currently kept in artifical hives.

Frieseomelitta longipes on brazil nut flowers

Trigona spinipes on cashew flowers

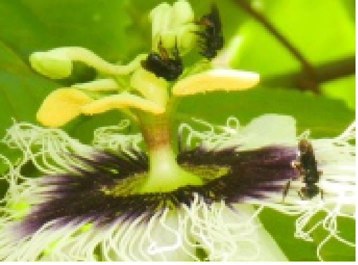


Trigona sp. on coffee flowers

Stingless bee on a kiwi flower

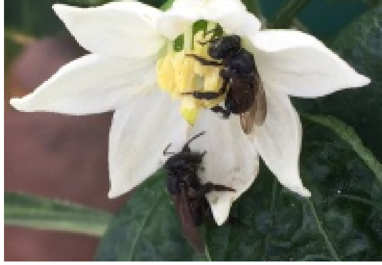
Natural occurrence and management

Stingless bees usually nest in hollow tree trunks or branches, abandoned termite nests, crevices between rocks or in belowground cavities. Stingless bees can be kept by beekeepers in their original log hive eg. when a beekeeper is cutting the branch with the colony inside, or they take a nest to transfer it to a wooden box to make hive control or honey and propolis harvesting easier. Meliponiculture (keeping stingless bees in artifical nest boxes) has a long tradition in Brazil and tradionally beekeepers keep each colony inside a wooden box without divisions. Later boxes were developed that allow nest divisions and honey extraction without damaging the colony. Today there are several box types for keeping stingless bees available and the hives developed in Embrapa Amazonia Oriental have different diameter entrances adapted to the size of different species. Stingless bee species like *Melipona flavolineata*, *Melipona fasciculata*, *Melipona quadrifasciata*, *Scaptotrigona depilis*,



Stingless bees (*Trigona* sp.) on a passion fruit flower

Trigona sp. on a sesame flower

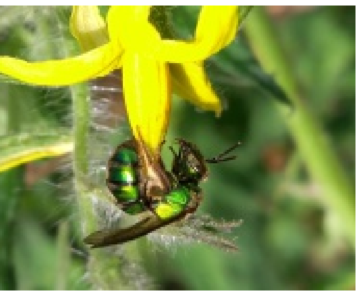


Trigona sp. on a sweet pepper flower

Scaptotrigona bipunctata and *Tetragonisca angustula* were shown to accept artifical boxes and visit many crop species in our guide. For example, these bees pollinate açaí palm (Contrere et al. 2011), strawberry or tomato (Imperatriz-Fonseca et al. 2006). Stingless bee hives are still not regularly used for crop pollination, despite the long tradition and the ongoing research.

Halictid bee on an anatto flower

Solitary bee on tomato flowers



Augochlora sp. on a tomato flower

Solitary wild bees

Colony size: No colony; these bees live solitary with one female provisioning five to fifty brood cells in one or few nests or semi-social bees with female bees nesting in nest aggregates and sometimes sharing tasks such as protecting nest entrances.

Size: 4 to 30 mm

Food resources: Pollen, nectar, honeydew

Nesting location: Diverse, above- and belowground

Further resources: Plant resin, oil, leaves and fiber, water

Solitary wild bees as crop pollinators: The majority of bee species are solitary. We still do not know the exact species numbers but at a minimum of 1000 solitary to semi-social bee species occur in Brazil (estimated from Freitas et al. 2009). Many solitary bees are food specialists and do not visit many different crops in contrast to the generalistic honeybees, bumblebees and stingless bees. For example the solitary squash bee *Peponapis* sp. collects only pollen of the plant family Cucurbitaceae. A squash bee that occurs in Brazil is *Peponapis fervens* (Giannini et al. 2010). Crops of the family Cucurbitaceae include melon, watermelon, pumpkin and zucchini (although we did not find flower visits of this bee to zucchini flowers). *Peponapis* species nest like many other solitary wild bees below ground. Almost all crops are visited by solitary wild bees. Solitary wild bees visiting a large number of crops in Brazil are carpenter bees, especially *Xylocopa frontalis* and *Xylocopa grisescens*, but also the communal nesting bee *Exomalopsis analis* and the oil-collecting bee species *Centris aenea*, *C. flavifrons* and *C. tarsata*. Below descriptions of the carpenter bees and the oil-collecting bees are given.

Natural occurance and management of solitary bees

Trap nest for solitary bees and wasps in a coffee plantation in Indonesia

Every solitary wild bee species has its own biology/ecology and hence different species live in different ecosystems, ranging from arid to humid and from lowland to mountain habitats. Bees nest in many different locations and substrates and require many different nest building materials. All in common is their need for the offspring to be undisturbed for the whole developmental period, which can be up to an entire year, and the favour for dry places for placing or rearing their offspring. As bees collect pollen from plants as larval food, which is commonly contaminated with bacteria and moulds high humidity in the nests decreases larval survival. Most solitary bees have a short flight period of only several weeks, the flight season can be up to 8 times a year or only once a year depending on the harschness of the environment and the therefore predictability of the flower resources the bees exploit.

Aggregations of ground-nesting bees establish in well drained soils, near to the food resources of the species

To promote solitary wild bees, many different native flower types should be grown near the crop fields to provide year-around foraging habitat. Above-ground nesting solitary bees can be promoted with nesting aids. For this bamboo or reed can be cut in 15 to 20 cm pieces, placed in a plastic tube to hang in trees adjacent to or in the crop fields. Different bamboo or reed diameters should be used to allow many different bee species to use the nesting aid. Drilled hardwood can also be used as nesting aids. Nesting aids should be placed at a sunny spot that is not exposed to strong wind and weather, and should be covered by a roof.

Below-ground solitary bees are difficult or nearly impossible to manage with nesting aids and should be promoted by habitat management. To encourage ground-nesting bees to nest in or around crop fields, open (with sparse vegetation), preferably sandy soils can be offered.

Nesting aids and open grounds are also used by many solitary waps species. Solitary bees and wasps are not aggressive and are both beneficial to farmers. Bees provide pollination services and wasps provide pest control by preying on caterpillars or aphids.

Large insect house for cavity-nesting solitary wild bee species. 10.000s of reed/bamboo sticks and holes drilled in the wood of different diameters provide a nesting space for many different species and generations. Such insect houses work in temperate and tropical regions

Xylocopa frontalis on a brazil nut flower

Xylocopa grisescens male on a passion fruit flower

Xylocopa grisescens female on a passion fruit flower

Xylocopa sp. on sesame flowers

Xylocopa grisescens on a watermelon flower

Xylocopa sp. on an anatto flower

Carpenter bees *Xylocopa* spp.

Sociality: Solitary

Colony size: No colonies are formed, but nesting of many females within the same location is facilitated through the high return potential of female bee offspring to their place of birth. Nest establishment can be increased by the provisioning of suitable nesting aids or natural nesting sites.

Size: 12 to 25 mm

Food resources: Pollen, nectar

Nesting location: Deadwood

Further resources: Clear space for perching and mating

Carpenter bees as crop pollinators: Carpenter bees visit many crop flowers and are known to be effective pollinators on anatto, brazil nut, common bean, cowpea, passion fruit, pumpkin, sesame, tomato, persimmon, watermelon, zucchini, melon, cotton, coffee, guava, sunflower

Natural occurrence and management of carpenter bees:

Carpenter bees build their nests, as their name suggests, in dead wood. Naturally, mainly in standing or fallen dead wood, especially tree trunks but poles and construction wood can also be attractive.

To promote carpenter bees, standing dead wood and dead branches should be conserved or actively established adjacent to the orchards where those bees are needed for pollination e.g. close to passion fruit fields. Nesting can also be artifically promoted through the provision of soft wood blocks of at least 30 x 30x 30 cm. The wood should be dry and constantly sheltered from rain and other sources of humidity. The use of sun absorbent material as rain shelter should be avoided as overheating of the nesting aids decreases occupation rates and larval survival. Occupation of the nesting aids can be facilitated through the provision of dummy entrances, holes of 30mm depth and 8 to 12mm diameter, that are drilled in an angle of about 30° pointing upwards into the lower 1/3 of the front of the nesting aid. The wood of the nesting aid should be horizontal with the grain simulating the orientation of a fallen tree trunk, as carpenter bees construct their nests along the grain which is facilitated by horizontal nest construction potential. However, vertical nests are built as well (Roubik 1995, Silva & Freitas 2018).

Carpenter bees also require a clear space with sky view in front of the nesting aids. To attract male bees, perching opportunities like poles should be located close to the nest. Further methods of carpenter bee nesting aid constructions are given in Freitas & Oliveira (2001) and Silva & Freitas (2018).

Oil-collecting bees *Centris* spp.

Centris analis on acerola flowers

Sociality: Solitary

Colony size: *Centris* bees do not form colonies, but nesting aggregations can be promoted.

Size: 9 to 32mm

Food resources: pollen, nectar, floral oil

Nesting location: Deadwood, sandy soil

Further resources: Resins, sand, mud

Oil-collecting bees as crop pollinators: Crop species commonly visited: Acerola, brazil nut, cashew, tomato, coffee, cotton, guava, passionfruit, persimmon

Natural occurrence and management of oil-collecting bees

Some oil-collecting species nest in pre-existing holes usually of wooden structures, others in the soil. Open, dry and sandy soils which are not disturbed heavily or deadwood in which other insects, like beetle and lepidopteran larvae drill their holes and eventually emerge from are the natural nesting sites. To promote *Centris* bees, holes of 5 to 9 mm and 8 to 12 cm depth, can be drilled in dry wooden blocks. The blocks need to be shelterd from rain or other sources of moisture. The wood should be drilled against the grain and hundreds of holes can be drilled with a minimum distance of 1 cm to each other into one or several wooden pieces. Only blind holes will be colonized by the bees, like *Centris analis* and *Centris tarsata*. The use of 4 to 6 cm wide, 50 cm high and 10 cm deep wooden beams equipped with 2 to 3 rows of holes is advisable as short dry wood pieces rarely form cracks. Cracks reaching the holes and hence the nests facilitate parasitism or nest destruction by mould. Another advantage of small wooden beams is that completed nests, indicated by a plug of resin or mud closing the holes, can carefully be transported to new locations.

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Continued lists for crops and pollinators

Continued list of citrus varieties grown in Brazil:
Lime fruits: Fino, Lima da Pérsia, Lima Roque, Lima Sorocaba, Lima Tardia, Lima Verde; Mandarin oranges: Afourer, Dancy, Ellenor, Fina, Fina Sodea, Imperial, Lee Marisol, Minneola, Monreal, Murcott, Nules, Orlando, Osceola Page, Pummelo (Pomelo), Robinson, Satsuma, SRA63, Tango, Temple, Washington Navel (Bahia)

Continued list of soybean main varieties grown in Brazil:
BRS 8160 RR, BRS 8381, BRS 8480, BRS 8590, BRS 8890RR, BRS 9090RR, BRS 9280RR, BRS Aurora, BRS Barreiras, BRS Corisco, BRS FavoritaRR,BRS Gralha, BRS Jiripoca, BRS Pétala, BRS Pétala, BRS Raimunda, BRS Tracajá, BRS ValiosaRR, BRS-Carnaúba, BRSGO 7460RR, BRSGO 7950RR, BRSGO 7960, BRSGO 8151RR, BRSGO 8360, BRSGO Chapadões, BRSGO Chapadões, BRSGO Luziânia, BRSMG 68 (Vencedora), BRSMG 740SRR, BRSMG 750SRR, BRSMG 7525, BRSMG 760SRR, BRSMG 790A, BRSMG 800A, BRSMG 800A, BRSMG 810C, BRSMG 811CRR, BRSMG 850RR, BRS-Sambaíba, M 9144 RR, M6009 RR, M6707 RR, M7211 RR, M7639 RR, M7908 RR, M8221 RR, M8230 RR, M8527 RR, M8766 RR, M8849 RR, M8867 RR, M9056 RR, MG/BR46 (Conquista)

Continued list of watermelon main varieties grown in Brazil:
Crimson Sweet, Fiesta, Giza I, Intruder, Kaho, Leeby, Leopard, Malali, Mickylee, Millionaire, Minipol, Polimore, Quetzali, Royal Jubilee, Royal Sweet, Sakata, Samara, Shadow, Shamhor, Shipper, SP-1, Sugar Baby, Sunshade, Tri-X 313, Yellow Elongate, Yellow Skin

Continued list of canola references:
Oliveira, 2017; Oz et al. (2008); Picard-Nizou et al. (1995); Pierre (2001); Pierre et al. (2010); Sabbahi et al. (2006); Shakeel et al. (2015); Steffan-Dewenter (2003); Tomm (2013); Williams (1985); Williams& Simpkins (1989); Witter et al. (2014)

Continued list of sunflower references:
Morgado et al. (2002); Nderitu et al. (2009); Neiva (2015); Oz et al. (2009); Parker (1981a,b); Parker & Frohlich. (1983); Pisanty et al. (2014); Saez et al. (2012); Skinner (1987); Tepedino & Parker (1982); Toledo et al. (2011); Wilson et al. (2016)

Continued list of cotton flower visitors and pollinators

Common name	Scientific name	Sociality
Oil-collecting bee	*Centris* sp.	Solitary
Orchid bee	*Eufriesea auriceps*	Solitary
Orchid bee	*Eulaema nigrita*	Solitary
Sweat bee	*Augochlora dolichocephala*	Solitary/Social
Sweat bee	*Augochlora esox*	Solitary/Social
Sweat bee	*Augochlora thalia*	Solitary/Social
Sweat bee	*Augochloropsis patens*	Solitary/Social
Sweat bee	*Pseudaugochlora graminea*	Solitary/Social
Sweat bee	*Augochlorella acarinata*	Solitary/Social
Sweat bee	*Augochlora* sp.	Solitary/Social
Sweat bee	*Augochloropsis* sp.	Solitary/Social
Sweat bee	*Pereirapis* sp.	Solitary
Sweat bee	*Ceratalictus* sp.	Solitary
Other bee	*Lithurgus huberi*	Solitary
Other bee	*Alepidosceles imitatrix*	Solitary
Other bee	*Exomalopsis analis*	Solitary
Other bee	*Diadasina riparia*	Solitary
Other bee	*Exomalopsis fulvofasciata*	Solitary/Social
Other bee	*Exomalopsis auropilosa*	Solitary/Social
Other bee	*Ptilothrix plumata*	Solitary
Other bee	*Acamptopoeum prinii*	Solitary
Other bee	*Tapinotaspoides serraticornis*	Solitary
Other bee	*Exomalopsis* sp.	Solitary/Social
Other bee	*Rhophitulus* sp.	Solitary

Continued list of canola flower visitors and pollinators

Common name	Scientific name	Sociality
Sweat bee	*Neocorynura* sp.	Solitary/Social
Sweat bee	*Halictus* sp.	Solitary/Social
Sweat bee	*Lasioglossum* sp.	Solitary/Social
Sweat bee	*Augochloropsis* cf. *cupreola*	Solitary/Social
Sweat bee	*Augochloropsis melanochaeta*	Solitary/Social
Sweat bee	*Augochlorella*	Solitary/Social
Sweat bee	*Augochlora amphitrite*	Solitary/Social
Sweat bee	*Augochlora* cf. *francisca*	Solitary/Social
Sweat bee	*Caenohalictus tessellatus*	Solitary/Social
Sweat bee	*Paroxystoglossa brachycera*	Solitary/Social
Sweat bee	*Pseudagapostemon olivaceosplendens*	Solitary/Social
Sweat bee	*Pseudagapostemon pruinosus*	Solitary/Social
Sweat bee	*Pseudagapostemon tesselatus*	Solitary/Social
Sweat bees	*Augochloropsis* sp.	Solitary/Social
Sweat bees	*Augochlora* sp.	Solitary/Social
Sweat bees	*Caenohalictus* sp.	Solitary/Social
Other bee	*Thygater mourei*	Solitary
Other bee	*Thygater* sp.	Solitary
Other bee	*Anthrenoides elioi*	Solitary
Other bee	*Anthrenoides petuniae*	Solitary
Other bee	*Anthrenoides ornatus*	Solitary
Other bee	*Psaenythia* sp.	Solitary
Other bee	*Rhophitulus reticulatus*	Solitary
Other bee	*Rhophitulus* sp.	Solitary
Other bee	*Exomalopsis perikalles*	Solitary
Other bee	*Hexantheda missionica*	Solitary
Other bees	*Exomalopsis* sp.	Solitary
Wasp	*Protonectarina sylveirae*	Social
Wasp	*Brachygastra lecheguana*	Social
Wasps	*Eucyrtothynnus* sp.	Solitary
Wasps	*Tiphia* sp.	Solitary
Wasps	*Campsomeris* sp.	Solitary
Beetle	*Astylus variegatus*	Solitary

Continued list of passion fruit flower visitors and pollinators

Common name	Scientific name	Sociality
Other bee	*Acanthopus excellens*	Solitary
Other bee	*Oxaea austera*	Solitary
Other bee	*Oxaea flavescens*	Solitary
Stingless bee	*Scaptotrigona* sp.	Eusocial
Stingless bee	*Trigona* sp.	Eusocial
Sweat bee	*Augochlora* sp.	Solitary/Social
Sweat bee	*Augochloropsis* sp.	Solitary/Social

Continued list of sunflower flower visitors and pollinators

Common name	Scientific name	Sociality
Bumblebee	*Bombus* sp.	Social
Sweat bee	*Augochlora amphitrite*	Solitary/Social
Sweat bee	*Augochloropsis callichroa*	Solitary/Social
Sweat bee	*Augochlorella ephyra*	Solitary/Social
Sweat bee	*Augochlora* aff. *Semiramis*	Solitary/Social
Sweat bee	*Pseudaugochlora* sp.	Solitary/Social
Leafcutter bee	*Megachile angularis*	Solitary
Leafcutter bee	*Megachile paulistana*	Solitary
Leafcutter bee	*Eumegachile* sp.	Solitary
Leafcutter bee	*Megachile* sp.	Solitary
Long-horned bee	*Melissodes nigroaenea*	Solitary
Long-horned bee	*Melissoptila tandilensis*	Solitary
Long-horned bee	*Thygater analis*	Solitary
Long-horned bee	*Melissodes* sp.	Solitary
Carpenter bee	*Xylocopa augusti*	Solitary
Carpenter bee	*Xylocopa carbonaria*	Solitary
Carpenter bee	*Xylocopa grisescens*	Solitary
Carpenter bee	*Xylocopa suspecta*	Solitary
Carpenter bee	*Xylocopa* sp.	Solitary
Small carpenter bee	*Ceratina* sp.	Solitary
Sweat bee	*Agapostemon* sp.	Solitary/Social
Sweat bee	*Pseudagapostemon* sp.	Solitary/Social
Sweat bee	*Halictus* sp.	Solitary/Social
Sweat bee	*Dialictus* sp.	Solitary/Social
Sweat bee	*Paroxystoglossa* sp.	Solitary/Social
Sweat bee	*Lasioglossum* sp.	Solitary/Social
Sweat bee	*Megaloptina* sp.	Solitary/Social
Orchid bee	*Euglossa cordata*	Solitary
Orchid bee	*Eulaema nigrita*	Solitary
Other bee	*Hypanthidium* sp.	Solitary
Other bee	*Melissoptila* sp.	Solitary
Other bee	*Oragapostemon* sp.	Solitary
Other bee	*Oxaea* sp.	Solitary
Other bee	*Diadasia* sp.	Solitary
Other bee	*Doeringiella*	Solitary
Other bee	*Nomada* sp.	Solitary
Other bee	*Exomalopsis* sp.	Solitary
Other bee	*Exomalopsis analis*	Solitary
Other bee	*Exomalopsis auropilosa*	Solitary
Southern green shield bug	*Nezara viridula*	Solitary
Beetle	*Astylus atromaculatus*	Solitary
Bird	*Chlorostilbon aureoventris*	Solitary

Continued list of sweet pepper flower visitors and pollinators

Common name	Scientific name	Sociality
Masked bee	*Hylaeus tricolor*	Solitary
Other bee	*Exomalopsis analis*	Solitary
Other bee	*Exomalopsis auropilosa*	Solitary
Other bee	*Exomalopsis fulvofasciata*	Solitary
Wasp	*Polybia* sp.	Social
Fly	*Toxomerus* sp.	Solitary
Cucurbit Beetle	*Diabrotica speciosa*	Solitary

Continued list of tomato flower visitors and pollinators

Common name	Scientific name	Sociality
Oil-collecting bee	*Epicharis flava*	Solitary
Oil-collecting bee	*Epicharis* sp.	Solitary
Oil-collecting bee	*Centris* sp.	Solitary
Oil-collecting bee	*Epicharis* sp.	Solitary
Orchid bee	*Eulaema nigrita*	Solitary
Orchid bee	*Euglossa* sp.	Solitary
Long-horned bee	*Thygater analis*	Solitary
Sweat bee	*Augochloropsis electra*	Solitary/Social
Sweat bee	*Pseudaugochlora erythrogaster*	Solitary/Social
Sweat bee	*Augochloropsis callichroa*	Solitary/Social
Sweat bee	*Pseudaugochlora graminea*	Solitary/Social
Sweat bee	*Augochloropsis smithiana*	Solitary/Social
Sweat bee	*Acamptopoeum prinii*	Solitary/Social
Sweat bee	*Augochloropsis cupreola*	Solitary/Social
Sweat bee	*Exomalopsis fulvofasciata*	Solitary/Social
Sweat bee	*Pseudaugochlora indistincta*	Solitary/Social
Sweat bee	*Augochloropsis* sp.	Solitary/Social
Sweat bee	*Lasioglossum* sp.	Solitary/Social
Sweat bee	*Pseudaugochlora* sp.	Solitary/Social
Sweat bee	*Halictus* sp.	Solitary
Sweat bee	*Anthophora* sp.	Solitary/Social
Sweat bee	*Augochlora* sp.	Solitary/Social
Other bee	*Exomalopsis analis*	Solitary
Other bee	*Exomalopsis auropilosa*	Solitary
Other bee	*Oxaea flavescens*	Solitary
Other bee	*Exomalopsis minor*	Solitary
Other bee	*Exomalopsis* sp.	Solitary

Continued list of zucchini flower visitors and pollinators

Common name	Scientific name	Sociality
Sweat bee	*Agapostemon* sp.	Solitary
Sweat bee	*Pseudaugochlora* sp.	Solitary/Social
Sweat bee	*Augochlora* sp.	Solitary/Social
Sweat bee	*Ceratalictus* sp.	Solitary/Social
Sweat bee	*Dialictus* sp.	Solitary/Social
Oil-collecting bee	*Epicharis* sp.	Solitary
Other bee	*Thygater analis*	Solitary
Other bee	*Exomalopsis analis*	Solitary
Other bee	*Exomalopsis auropilosa*	Solitary
Other bee	*Neocorynura*	Solitary
Other bee	*Pseudagapostemon* sp.	Solitary
Orchid bee	*Eulaema* sp.	Solitary

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Acerola/Acerola

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Mainly crop pollination and production:

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Cowpea/Feijão-caupi

Mainly pollinators and flower visitors:

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Cupuaçu/Cupuaçu

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Venturieri, G.A. (1993) Cupuaçu: a espécie, sua cultura, usos e processamentos. Belém: Clube do Cupu, 108p., Brazil

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Venturieri, G.A. (2011) Flowering levels, harvest season and yields of cupuassu (*Theobroma grandiflorum*), Acta Amazonica 41: 143-152

Guava/Goiaba

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Kiwifruit/Kiwi

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Lychee/Lichia

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Marin-Acosta J.C. (1969) Insects living on the papaya tree (*Carica papaya*) in Venezuela. Agronomia Tropical (Maracay), Venezuela

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Passionfruit/Maracujá

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Peach/Nectarina

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Mainly pollinators and flower visitors:

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Giannini T.C., Boff S., Cordeiro, G.D. et al. (2015) Crop pollinators in Brazil: a review of reported interactions. Apidologie 46: 209-223

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Plum/Ameixeira

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Pumpkin/Abobora

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Amarante C.V.T., Macedo A.F. (2000) Fruit set and fruit growth of 'Tetsukabuto' squash treated with the sodium salt of alfa-naphthaleneacetic acid. Horticultura Brasileira 18: 212-214

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Rambutan/Rambutã

Mainly pollinators and flower visitors:

Leão K.S. (2014) Manejo de Scaptotrigona sp. (Hymenoptera, Apidae, Meliponini) para polinização da rambuteira (*Nephelium lappaceum*) Dissertação Mestrado, Universidade Federal do Pará, Belém, Brasil, 73p., Brazil

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Sesame/Gergelim

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Sarker A.M. (2004) Effect honeybee pollinisation on the yield of rapeseed, mustard and sesame. Geobros 31: 49-51

Soursop/Graviola

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Aguiar J.R., Bueno D.M., Freitas B.M. et al. (2000) Tecido nutritive em flores de gravioleira, *Annona muricata* L. Ciência Agronômica 31: 51-55

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Strawberry/Morango

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Sunflower/Girassol

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Sweet pepper/Pimentão

Mainly pollinators and flower visitors:

Raw A. (2000) Foraging behaviour of wild bees at hot pepper flowers (*Capsicum annuum*) and its possible influence on cross pollination. Annals of Botany 85: 487-492

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