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Pollination in tree spices

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Abstract
Pollination is the act of transferring pollen grains from the male anther of a flower to the female stigma. The goal of every living organism, including plants, is to create offspring for the next generation. Seeds can only be produced when pollen is transferred between flowers of the same species. Pollination being a process of sexual reproduction helps to maintain plant characters. The dioecious nature of nutmegs has long been a problem for nutmeg cultivation, because while some male trees are needed for pollination, only female trees produce the cash crop. In clove viable seeds have not been produced from selfed flowers, indicating that the flowers require cross- pollination. The type of pollination in cambodge is cross pollination through Anemophily. Characteristics of pollen grains revealed the chance of wind pollination. Protogynous dichogamy in cinnamon leads to cross pollination. *Tamarindus indica* is a highly cross-pollinated crop and the pollination is through entomophilous and implicated ants particularly red ants. Common Juniper is dioecious in nature, predominantly cross pollinated. Wind pollination plays an important role in common juniper. Knowledge of pollination in tree spices is limited and is important with respect to crop improvement, production and biodiversity in tree spices. Most of the tree spices are cross pollinated thus increasing variability in population and provides chances for the evolution of new varieties and species and also pollinators in creating diversity among them.

Keywords: Pollination, droplets, protogyny, dichogamy, fertilization

Introduction
Pollination is critical for food production and human livelihoods, and directly links wild ecosystems with agricultural production systems. Pollination system started with the evolution of plants. It was around 125-115 million years ago that a new pollination strategy developed and angiosperms first appeared. Animal mediated pollination contributed to the sexual reproduction of over 90% of the species of modern angiosperms. Knowledge of pollination system is thus broadly relevant with applications in the field of ecology, evolutionary biology, conservation, entomology and horticulture

Pollination
Pollination is the transfer of pollen from a male part of a plant to a female part of a plant, later enabling fertilization and the production of seeds, most often by an animal or wind (Barrows, 2011) [5].

History of pollination
The German physician and botanist Rudolf Jakob Camerarius (1665-1721) is credited with the first empirical demonstration that plants reproduce sexually. Camerarius discovered the roles of the different parts of flower in seed production. While studying certain bisexual (with both male and female reproductive organs) species of flowers, he noted that a stamen (male pollen-producing organ) and a pistil (female ovule-producing organ) were both needed for seed production. The details of fertilization were discovered by scientists several decades after Camerarius's death. Among the many other scientists who followed Camerarius's footsteps in the study of pollination, one of the most eminent was Charles Darwin. In 1862, Darwin published an important book on pollination: *The Various Contrivances by which Orchids Are Fertilized by Insects*. In part, Darwin wrote this book on orchids in support of his theory of evolution proposed in *The Origin of Species*, published in 1859. Darwin demonstrated that many orchid flowers had evolved elaborate structures by natural selection in order to facilitate cross-pollination. He suggested that orchids and their insect pollinators evolved by interacting with one another over many generations, a process referred to as coevolution. One particular example illustrates Darwin's powerful insight. He studied dried specimens of *Angraecum sesquipedale*, an orchid native to Madagascar.

The white flower of this orchid has a foot-long (30 cm) tubular spur with a small drop of nectar at its base. Darwin claimed that this orchid had been pollinated by a moth with a foot-long tongue. He noted, however, that his statement "has been ridiculed by some entomologists." And indeed, around the turn of the century, a Madagascan moth with a one-foot-long tongue was discovered. Apparently, the moth's tongue uncoils to sip the nectar of *A. sesquipedale* as it cross-pollinates the flowers. Darwin continued his studies of pollination in subsequent years. In 1876, he wrote another important book on pollination biology, *The Effects of Cross and Self Fertilization in the Vegetable Kingdom*. The Austrian monk and botanist Johann Gregor Mendel (1822-1884) also conducted important pollination studies in Brno (now in the Czech Republic) in the mid-1800s. He studied heredity by performing controlled cross-pollinations of pea plants thereby laying the foundation for the study of heredity and genetics.

Importance of pollination

Ranga, (2019) reported the importance of pollination

Coevolution: pollinators evolved by interacting with one another over many generations, a process referred to as coevolution. Mutual adaptation of flowers and pollinators and their interdependence are considered to be results of their long and intimate coevolutionary relationship. Many flower forms evolved due to the selective pressure of pollinators.

Helps in the maintenance of plant resilience: Sexual reproduction enhances the genetic vitality and adaptability of plants to changing environmental and external conditions. Pollination being a process of sexual reproduction helps to maintain plant characters.

Help in the sustenance of plant distribution: The seeds are carried by animals as a part of eating the fruit and dropped in different places. These seeds grow into plants in the distant place from mother. Such distance distribution is kept alive due to the distribution of pollen to distant parts.

Supports plant breeding: The plant breeding is done by many scientists like Gregor Mendel, Hugo de Vries, etc. was through the use of techniques like self-pollination, cross-pollination, etc. This pollination is quite an easy method for genetic variation studies compared to other methods.

Supplies food: In biotic pollination, insects and birds land over flowers to drink nectar. In doing so, some pollen sticks to their limbs which are dispersed on to other flowers. So, flowers provide food in the form of nectar to insects and birds. Hence, honey bees collect honey from flowers which are again stored in the honeycomb. We humans take it for food. Thus, pollination indirectly provides food to animals.

Supports reproduction in animals Many birds and insects have breeding time around the flowering season. This is because, during the flowering season, insects can find food and support their offspring. These larva in-turns become food for birds. Hence, many birds and insects reproduce during the flowering season. It is experimentally found that as the time for flowering changes, the reproduction cycle of birds and insects too change.

Enhance agriculture yield: In agriculture, there is a practice of manual pollination (mechanical pollination). Farmer uses a soft cloth to rub over different flowers like a sunflower. Doing so will enhance pollination

Classification of pollination

Pollination is the process involving transfer of pollen from anthers to the stigma. The agent causing this transfer is called the pollinator. Normally, angiosperms exhibit two kinds of pollination modes:

Self-pollination or selfing

When pollination takes place within a flower, this is called self-pollination. Self-pollination will take place if: a) Flowers are bisexual and have stigmas and anthers at the same heights (stamens and style are of the same length); b) both the sexes mature simultaneously (protandry or protogyny are absent); e) contact of newly dehisced anthers (releasing fresh pollen) with the receptive stigma is imminent. Proximity of anthers to stigma under the above conditions should result into self-pollination. If selfing results in fertilization, this should indicate atleast some occurrence of strict inbreeding.

Cross-pollination or outcrossing

When pollen from one flower is carried to the stigma of another, this is called cross-pollination. Here an external agent is required for accomplishing the pollen transfer. Outcrossing is important in plants where: a) either flowers or plants are unisexual; b) anthers and stigma (stamens and styles) of same flower is at different heights (i.e., stamens and style are of different lengths); e) sexes mature at different times (presence of protandry or protogyny); ell) there is no contact of dehisced anthers with the stigma of same flower during their functional phase; e) above all, plants are self-incompatible i.e. (pollen from a plant cannot be utilized by its own flowers). Outcrossing is brought out by two kinds of agents, abiotic and biotic.

Different kinds of abiotic pollination have been recognized

1. Gravity-pollination (geophily) is found in self-pollinated plants. Here some pollen is expected to fall down on the receptive stigmas of other flowers due to gravity and may pollinate the flowers. However, geophily is highly unreliable and is a rare and insignificant pollinating agent.
2. Water-pollination (hydrophily) is found only in some water plants where inflorescences float or are submerged. However, many freshwater plants produce aerial inflorescences.
3. Wind-pollination (anemophily) is found in many plant families including crop plants especially grasses.

Biotic pollination naturally falls into several distinctive classes

1. Pollination of by insects (entomophily), e.g., by beetles (cantharophily), flies (myophily), bees (melittophily), butterflies (psychophily), moths (phalaenophily)
2. Pollination by invertebrates like snails and slugs (malacophily)
3. Pollination by vertebrates, such as birds (ornithophily), and bats (chiropterophily)

Pollination syndrome: According to Fenster *et al*., (2004) [11] Pollination syndromes were first defined by Federico Delpino as suites of floral traits associated with particular pollinator groups. plants and animals exploit each other for their own advantage.

Tree spices

Spices which are originating from tree crops. These are high value crops which have huge demand in Indian market. Tree spices are precious spices which have commercial, industrial and medicinal importance.

Table 1: Tree spices grown in India

SN	Botanical name	Family	Common name	Parts used
1	*Myristica fragrans* Houtt.	Myristicaceae	Nutmeg	Kernel, Aril
2	*C. verum* Bercht & Presl.	Lauraceae	Cinnamon	Bark, leaf
3	*Cinnamomum aromaticum* Nees	Lauraceae	Cassia/ Chinese cassia	Bark, leaf
4	*C. tamala* Nees	Lauraceae	Tejpat/ Indian cassia	Leaf, bark
5	*Syzygium aromaticum* (L.) Merr. & Perry	Myrtaceae	Clove	Flower bud
6	*Garcinia gummi-gutta* (L.) Robs.	Clusiaceae	Cambogia	Pericarp of Fruit
7	*G. indica* (Thouars) Choisy	Clusiaceae	Kokam	Pericarp Fruit
8	*Pimenta dioica* (L.) Merr.	Myrtaceae	Allspice, Pimento	Immature fruit, Leaf
9	*Murraya koenigii* (L.) Sprengel	Rutaceae	Curry leaf	Leaf
10	*Tamarindus indica* L.	Caesalpiniaceae	Tamarind	Fruit
11	*Illicum verum* Hook	Illiciaceae	Star anise	Fruit
12	*Juniperus communis* L.	Cupressaceae	Juniper	Fruit
13	*Laurus nobilis* L.	Lauraceae	Bay leaf	Leaf
14	*Capparis spinosa* L.	Capparidaceae	Caper	Flower buds
15	*Punica granatum* L.	Punicaceae	Pomegranate	Seed

Nutmeg

The Botanical name of nutmeg *Myristica fragrans* Houtt. It belongs to family Myristicaceae and native of Indonesia. It is commonly called as Twin spices (Nutmeg and mace).

Nutmeg, both a spice and a pantropical plant family, is important for three reasons. First, although not as valuable as in times past, nutmeg, the spice obtained from the seed, the ruminant endosperm of *Myristica fragrans* (and a few related species), and mace, another spice from the reddish aril of the same plant, are important crops, primarily in Indonesia and Grenada, and while spices are not essential things, our eggnogs and other confections would be much duller without them. Second, the nutmeg family occupies a phylogenetic position near the base of angiosperms, the flowering plants, and may give clues to their ancestral traits. Third, members of the nutmeg family are important components of wet, lowland tropical rain forests, and their fruit is an important part of the diet of many birds and primates. In one respect or another, the reproduction of nutmegs is central for understanding everything from nutmeg cultivation to rain forest function and conservation. The dioecious nature of nutmegs has long been increased the percentage fruit set as compared to self-pollination or open pollination indicating the male trees in a population for improved fruit set. Only 20% of open pollinated flowers set fruits.96% of fruitset observed in hand cross pollination than natural pollination. No insect pollinators were observed (Aswathi *et al*., 2018) [4] The Botanical name of nutmeg *Myristica fragrans* Houtt. It belongs to family Myristicaceae and native of Indonesia. It is commonly called as Twin spices (Nutmeg and mace).

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Table 2: Floral biology and pollen characterstics

Sl. No.	Floral characters	Observations
1	Anthesis time	5hrs after sunset
2	Anther dehiscence	Prior to anthesis
3	Abscission of flowers	24-48hrs after anthesis
4	Stigma receptivity	From anthesis upto 2-3 days
5	Pollen ovule ratio	8,01,000/1

Armstrong and Drummond, (1986) [2]

Factors affecting pollination in nutmeg

1. **Sex and spacing:** In nature nothing close to a unitary sex ratio has been found, that allow for intersexual differences in resource use, longevity and survival, or aggregation for increasing pollination efficiency. No one knows how nearest neighbor distances affect pollination, but it certainly depends upon the pollen vector (Opler and Bawa, 1978) [34].

2. **Floral characteristics affecting pollination:** Pistillate flowers are solitarily and appear receptive for 2- 3 days. Staminate flowers-indeterminate and function for 1 night. Both types of flowers are strongly fragrant. *Formicomus braminus* (Anthicidae, ant-mimicking flower beetles), appears to be the best candidate for an effective pollinator of nutmeg in the area of the study, although other species of small beetles may be involved. Pollen is the only evident pollinator reward. Pistillate flowers produce no reward, and spatial constraints of the perianth and stigma appear to prevent beetles from entering the flowers. Pollen carried on the beetle's head or body would be deposited on the stigma when the insect attempts to enter the flowers. This is the first report of a food-deception automimicry in a cantharophilous pollination system. (Armstrong and Drummond, 1986) [2].

Insect visitors and pollinators

Primary pollinators are beetles and thrips**.** For *Myristica insipida* in Queensland, Australia, nine beetle species belonging to five families were reported. (Armstrong, 1997) [3]. Studies on *Gymnacranthera* and *Knema* species suggested Curculionids, Staphylinids and Chrysomelids as potential pollinators. (Momose *et al*., 1998b, Momose, 2005) [27, 26].

Insect pollinator syndrome

Myristica conforms to a generalized, small-insect pollinator syndrome. (Bava *et al*., 1985 [7] and Givnish, 1980) [15]. Small differences in flower structure can greatly change how effective diverse insects are as pollinators. For example, in *Myristica fragrans* and *M. insipida* insect entry to female flowers is restricted by the tight fit of the perianth *around* the stigma, while flowers of *M. fatua* and *M. dactyloides* have a more open perianth easily entered by small insects. (Sharma and Shivanna, 2011) [41].

Clove

The botanical name of clove is *Syzygium aromaticum* (L.) Merr. and Perry. It belongs to family Myrtaceae. The economic part is dried unopened flower bud and native of Moluccas Island of Indonesia

Table 3: Floral biology and pollen characteristics

Floral characters	Observations
Anthesis time	1.30pm (3.30 p.m. and 4.30 p.m.)
Anther dehiscence time	24hrs before anthesis
Anther dehiscence mode	Longitudinal
Stigma receptivity	5thday of anthesis
Pollen viability	48hrs after anthesis

Thangaselvabai *et al*., (2010) [45]

Pollination studies in clove

In clove viable seeds have not been produced from selfed flowers, indicating that the flowers require cross- pollination and also concluded that, since vegetative propagation had never been accomplished, pollination from the breeding standpoint becomes important (Tidbury, 1949) [48]. In clove fertile fruits were not obtained from bagged flowers and cross pollination was necessary for seed production (Purseglove, 1968) [38].

Pollinators

Clove flowers fertilization was by some insect. (Ridley, 1912). Clove flowers are visited by bees (Tidbury, 1949) [48]. Clove flowers are visited and apparently cross-pollinated by bees (Pursglove, 1968).

Artificial cross pollination in clove

The technique reported here is based on the observations of POOL & BERMAW~E (1986), together with subsequent investigations in the field, and describes a simple and practical procedure for artificial cross pollination in clove.

Procedure

1. The initial step involves locating flowers that are ready for emasculation. The correct stage of development for emasculation is two days before flower opening and this stage can be recognised by the existence of a small (0.5 mm) gap between the corolla and the calyx tube. If the gap is larger than 0.5 mm the flower is too old for emasculation. It is sometimes possible to find clusters with two or three flowers ready for emasculation at the same time. All flowers that are at stages either too early or too late for emasculation should be removed from the cluster.
2. Emasculation is accomplished by removing the corolla with the thumb nail and, with a pair of line forceps, carefully prising away the stamens at their position of attachment to the calyx tube. If this step is not conducted with care, damage to the stigma and style, with subsequent abscission of the flower can result. During the removal of stamens, it is common for anthers to become detached from filaments and adhere to the stigma or style. In such cases these anthers should be removed.
3. Emasculated flowers should be immediately enclosed in muslin bags which are tied into position with raffia. It is important that the stigmas of emasculated flowers are not in contact with the inside surface of the bags. Our experience has shown that muslin with a mesh size of 0.2 x 0.2 mm is adequate and a bag size of approximately 7.5 x 15.0 cm is most practicable. Raffia should be tied tightly enough to prevent ants entering but not so tightly as to damage the supporting stems.
4. The optimal time for pollination is four days after emasculation. This stage of development is equivalent to two days after flowers would have opened naturally. Muslin bags should be temporarily removed and the anthers of flowers from desired pollen donors must be gently rubbed several times across the stigma of the flower to be pollinated. Flowers used for pollinating should have been open for between 24 and 48 hours. If necessary, pollination can be carried out using stored pollen which should be applied with a small paintbrush. Immediately after pollination flowers should be re enclosed in muslin bags as before.
5. Four weeks after pollination muslin bags may be removed. By this time fertilized flowers will exhibit a pronounced swelling of the calyx tube, while flowers in which pollination has been unsuccessful will have abscissed. Muslin bags should now be exchanged for wide mesh string or plastic bags. These are designed to maintain conditions as similar as possible to those of the natural environment and to prevent developing fruits from being lost should they fall. The mesh size of the string or plastic bags is approximately 1.0 x 1.0 mm and the dimensions are 7.5 x15.0 cm as before.

6. Fruit maturity is reached between three and four months after pollination. Mature fruits are normally oblong and of a deep purple colour. When this stage has been attained bags may be removed and fruits can be harvested.

Cambodge

The botanical name is *Garcinia gummi-gutta* L. N. Robson Desr. It belongs to family Clausiaceae. The origin of cambodge is South Asia (Thailand and India). The economic part is dried rind of fruit.

Table 4: Floral biology and pollen characterstics

Floral character	Female flower	Male flower
Anthesis time	4.30pm-6.30pm	4.30pm-6.30pm
Anther dehiscence time	-	Before anthesis
Anther dehiscence mode	-	Longitudinal slit
No. of anthers/flower	-	19.9±0.7
No. of ovules/flower	5.4±0.31	-
Pollen-Ovule ratio	783:1	-
Stigma type	Wet	-
Stigma receptivity	7.00pm	-
Pollen size	-	24.6±0.27µm
Pollen shape	-	Spherical
Pollen type	-	Bi, tetra or pentaporate
Pollen viability (%)	-	23.6±6.4
Pollen fertility (%)	-	94.1±0.66
Flower longevity	18hrs	18hrs

Aswathi *et al*., (2018) [4]

Types of trees

Two types of trees were observed by George *et al*., (1992) [13] are functionally male and functionally female with hermaphrodite flowers. The flowering season is end of January to early March and flowering type is androdioeciuos (Aswathi *et al*., 2018) [4].

Pollination studies in Cambodge

Garcinia is often cross-pollinated crop. (Shirly, 1994) Presence of pollen grains revealed the chance of wind pollination. Hand pollination with pollen from male flowers increased the percentage fruit set as compared to self-pollination or open pollination indicating the male trees in a population for improved fruitset. The type of pollination in cambodge is cross pollination through Anemophily. Characteristics of pollen grains revealed the chance of wind pollination. Hand pollination with pollen from male flowers increased the percentage fruit set as compared to self-pollination or open pollination indicating the male trees in a population for improved fruit set. Only 20% of open pollinated flowers set fruits.96% of fruitset observed in hand cross pollination than natural pollination. No insect pollinators were observed (Aswathi *et al*., 2018) [4].

Characterstics of wind pollinated plants

According to Whitehead, (1969) wind pollinating plants possess the following characters. Wind pollinating plants possess large number of small sized pollen grains (between 20-40µm in diameter), Both stigma and anthers were exposed, Large receptive surface of stigma, Pollen grains were dispersed at the right time in the year that is dry season. *Garcinia gummi-gutta* possess characters mentioned above.

Cinnamon

The botanical name is *Cinnamomum verum* Bercht & Presl. It belongs to a family Lauraceae (Purseglove, 1969). The economic part of cinnamon is dried inner bark and native of Srilanka. Among eight available cinnamomum species in Sri Lanka, Cinnamomum verum is indigenous and rest of the species are endemic to Sri Lanka (Joseph J, 1981) [31].

Floral biology

Flowering in cinnamon exhibits protogynous dichogamy due to which cross pollination takes place. Peak anthesis is from11am to 12 noon and Stigma receptivity is on the day of anthesis. (Thangaselvabai *et al*., 2009) [46].

Flowering behavior of cinnamon

Joseph (1981) reported that every flower opens twice in two stages. In stage one on the first day, when a flower opens, its stigma is receptive, and there is no dehiscence of anthers, and the stamens of the first whorl and those of the third whorl appear fused. The flower closes in the afternoon. In stage two, the next day, the anthers dehisce 30-60 minutes after the flower opening. After about five hours the flower closes and will not open again. This type of dichogamy is termed as synchronized dichogamy or as protogynous dichogamy.

Protogynous dichogamy in cinnamon leads to cross pollination. Each flower of cinnamon opens on two consecutive days; on the first day the stigma is receptive and on the second day the anthers undergo dehiscence (Ravindran *et al*., 2004). The majority of the cinnamon plantations in Sri Lanka and elsewhere have originated from highly cross-pollinated seeds. However, no reported studies exist on the variability of individuals caused by the natural cross-pollination of cinnamon (Liyanange *et al.*, 2020).

Pollinators

Honey bees are the most active as they are noted most often on blooming cinnamon trees. Important species are *Apis cerana*, *Apis dorsata* and *Apis florea* (Mohankumar *et al*., 1985) [25]. Cinnamon is usually pollinated by insects, especially flies and honey bees (Ravindran *et al*., 2004).

Tamarind

The botanical name is *Tamarindus indica* L. It belongs to a family Fabaceae. The economic part of cinnamon is fruit pulp and native of Eastern Tropical Africa.

Floral biology and pollen characterstics

Flowers are bisexual and tamarind is predominantly cross pollinated. Red ants play an important role in pollination.

Table 5: Floral characters and pollen characterstics

Floral characters	Observations
Anthesis time	8pm to 2am
Anther dehiscence	8.30am
Stigma receptivity	48hrs peak on the day of anthesis
Pollen viability	37-40ºC - 88% until 3 days 4ºC - 97% viable upto 100days
Pollen size	2 distinct sizes: 40µm-42µm and 22µm-27µm

Nagarajan *et al*., 1998 [31]

Pollination studies in tamarind

Although some aerobiological work recorded the incidence of

tamarind pollens in the air, wind movement of pollen do not appear the regular phenomenon and the pollengrains are not suited for dissemination in the wind as they are highly sticky (Subbareddi, 1970) [43]. *Tamarindus indica* is a highly cross-pollinated crop and thus necessitates involvement of some agent to move pollen from flower to flower within a plant or from plant to plant (Thimmaraju *et al*., 1975). *Tamarindus indica is* entomophilous and implicated ants particularly red ants, Oecophylla smaragdina in the pollination (Thimmaraju *et al*., 1975). *Tamarindus indica* is probably the entomophilous. (Pursglove, 1977). Ants of *Camponotus compressus* species play a little role in pollination and the rock bee *Apis dorsata* successfully and effectively pollinates tamarind on the GKVK forest at Bengaluru (Bhaskar and Mahadevaiah, 1990) [8].

Fruit set in tamarind

In tamarind fruit set is very poor (1-2%) resulting in large scale abcission of flowers as well as fruits during various stages of development. Very low fruit setting noticed in tamarind under open pollination is not a rarity, such a condition is quite common in many tropical trees (Bawa, 1974). A low fruit set mean value is normally an indicator of pollinator limitation (Calwo, 1990) [9]. While specialized anther arrangement makes pollinator interaction effective herkogamy promotes a strongly out crossing breeding system in tamarind under natural conditions (Harder and Barrett, 1993 [16] Nilsson, 1988) [33]. High fruit settting in controlled crosses and negligible fruit set in selfing are ample evidences of self incompatability (Mukherjee *et al*., 1968) [30]. This is severe especially when monoculture is practiced, it can be overcome by introducing captive honey bees. (Moncur *et al*., 1995) [28].

Causes of poor fruit set

Failure of fertilization, Sterility, Higher percentage of defective pollen grains, Slow growth of pollen grains, Early degeneration of pollen grains (Giribabu, 2007) [14].

Tamarind is an outcrossing species, but low fruit set observed in natural conditions is mainly due to pollinator limitation. Unique floral adaptations in this specie promotes out crossing under natural conditions. Hybridization is relatively easier with controlled crossing resulting an average of 84% fruit set. Monoculturing a single high yielding genotype is likely to result in fruiting failure due to extremely low levels of compatability with selfpollen, thus while developing commercial clonal orchards atleast 5 genotypes should be included. Since storage of pollen is quite simple samples can be easily exchanged or transferred across locations for conducting controlled crossing programmes. With clearly understood breeding system and standardized controlled pollination techniques tamarind needs to be exploited further for its genetic improvement.

Juniper

The botanical name is *Juniperus communis* L. It belongs to a family Cupressaceae. The economic part of cinnamon is fruit and native of Western Himalayas.

Pollination studies in Juniper

Common Juniper is dioecious in nature, predominantly cross pollinated. Wind pollination plays an important role in common juniper.

The extensive bibliography which is generalized in a number of reviews is devoted to the problem of pollination in Gymnosperms. (Doyle 1945, McWilliam, 1958, Owens *et al*. 1987, 1998, Anderson and Owens, 2000) [10,24,1]. The important role in pollination processes of the majority species in Cupressaceae, Taxaceae, Cephalotaxaceae families and many species in Podocarpaceae and Pinaceae families play the pollination droplet, more often accumulating on the top of the ovules in the reception period. Evolution of pollination mechanism in Gymnosperms went from entomo- to anemophily (Labandeira *et al*., 2007) [22]. Important role in the course of pollination (catching of pollen grains and its translocation to the top of nucellus) in *Juniperus communis* plays pollination droplet accumulating on the tips of integuments in receptation period.

Pollination droplet

The pollination droplet is a liquid secretion produced by the ovule and exposed outside the micropyle. (Doyle, 1945) [10].

Functions of pollination droplet

- The ovular secret serves mainly for catching of pollen grains.
- It also participates in cognizance processes.
- Prevents premature of exine rupture and shedding.
- Promotes growth and development of pollen tubes at initial stages of pollen germination.

Pollination droplet affecting pollination

After pollination of receptive ovules by pollen of juniper the full retraction of exudation secret has occur to the end less than for 4 hours. After pollination by alien pollen the full retraction of pollination droplets inside ovule has occurred only 12 hours later. In the absence of pollination, the exudation activity of apical zones of the nucellus proceeded not less than 60 hours. The sizes of droplets have thus increased to maximum, on the average, by 40%. Frequent cases of merging of droplets of two or all three ovules in one general for a macrostrobile a large droplet were observed. In 90 hours on tips of the majority of ovules already enough small droplets were observed, many ovules were without droplets, large droplets have remained only on individual ovules. In 120 hours at all not pollinated ovules has occurred full retraction of secretory liquids. (Surso, 2018) [44]

- Pollination regime in natural populations of this species is characterized by very short (no more than 4–6 hours) period of mass pollen dispersion.
- Pollination droplet plays an important role in the course of pollination in Juniper

Functional properties and chemical compound of pollination droplets deserve deeper studying

Table 6: Minor tree spices

op	Botanical name	Family	Origin	Economic part	Flowering type	Type of pollination	Mode of pollination	Pollinators	References
Pomegranate	*Punica grantum* L.	Lythraceae	Iran	Dried seed powder	Monoecious	Self-pollination and Cross pollination	Anemophily	*Camponotus spp, Apis spp* and *Papilio demoleus*	Nath and Randhawa, 1995b [32]
Indian cassia	*Cinnamomum tamala* Nees.	Lauraceae	North western Himalayas	Leaf, bark	Bisexual, monoecious	Cross pollination	Entomophily	Honeybees	Sharma and Nautiyal, 2011 [41]
Chinese cassia	*Cinnamomum aromaticum* Nees	Lauraceae	China	Leaf, bark	Bisexual	Cross pollination			Peter, 2007
Kokum	*Garcinia indica* Choisy.	Clusiaceae	Western ghats of India	Dried rind of fruit	Dioecious	Cross pollination			Peter, 2007
Star anise	*Illicium verum* Hook.	Illiciaceae	China	Fruit	Bisexual flowers	Cross pollination		Bees, wasp and fly	Forgetten pollinators, 1997
Curryleaf	*Murraya koenigii* Spreng.	Rutaceae	India	Leaf	Bisexual	Self-pollination			Parmar and Kaushal, 1982
Bayleaf	*Laurus nobilis* L	Lauraceae	Europe	Leaf	Dieocious	Cross pollination		*Apis mellifera, Bombus lucorum, Xylocopa violacea*	Pacini *et al*., 2014
Allspice	*Pimento dioica* (L) Merrill	Myrtaceae	Central America	Fruit	Structurally bisexual but functionally dioecious	Cross pollination		Insects and wind	Weiss, 2002

Conclusion

Pollination is mutually beneficial to the plants and pollinators. Self-pollination is of little ecological and economic significance to many tree spices. Cross-pollination leads to heterozygosity and provides chances of gene recombination. Cross-pollination by wind, water or gravity is of little importance due to the random nature. For the preservation of biodiversity in the ecosystem, conservation of pollinators and pollination services for plants are essential. Knowledge of pollination in tree spices is limited and is important with respect to crop improvement, production and biodiversity in tree spices. Most of the tree spices are cross pollinated thus increasing variability in population and provides chances for the evolution of new varieties and species and also pollinators in creating diversity among them.

References

1. Anderson ED, Owens JN. Microsporogenesis, pollination, pollen germination and male gametophyte development in Taxus brevifolia. An. Bot. 2000;86(5):1033-1042.
2. Armstrong JE. Drummond III, B.A., Floral biology of Myristica fragrans Houtt. (Myristicaceae), the nutmeg of commerce. Biotropica. 1986, 32-38.
3. Armstrong JE. Pollination by deceit in nutmeg (*Myristica insipida*, Myristicaceae): floral displays and beetle activity at male and female trees. Am. J Bot. 1997;84(9):1266-1274.
4. Aswathi P, Aswani K, Sabu M. Reproductive biology of Malabar tamarind (*Garcinia gummi-gutta* (L.) Rob. An endemic, medicinal and spice plant from Western Ghats. The Int. J Plant Reproductive Biol. 2018;4:65-68.
5. Barrows EM. Animal Behavior Desk Reference. A Dictionary of Animal Behavior, Ecology and Evolution (3rd Ed.). CRC Press LCC, Boca Raton, FL. 2011, 794.
6. Bawa KS. Breeding of tropical hardwoods: an evaluation of underlying bases, current status and future prospects. In Linnean Society symposium series. 1976.
7. Bawa KS, Perry DR, Beach JH. Reproductive biology of tropical lowland rain forest trees. Vol I. Sexual systems and incompatibility mechanisms. Am. J Bot. 1985;72(3):331-345.
8. Bhaskar V, Mahadevaiah YN. Rock bee pollination in tamarind (*Tamarindus indica* L.). Eleventh Intl. Cong. IUSSI, 1990. Oxford and IBH Pub. Co., New Delhi, India. 1990, 437-438.
9. Calvo RN. Inflorescence size and fruit distribution among individuals in three orchid species. Am. J Bot. 1990;77(10):1378-1381.
10. Doyle J. Developmental lines in pollination mechanisms in the Coniferales. Sci. Proc. R. Dublin Soc. 1945;24:43-62.
11. Fenster CB, Armbruster WS, Wilson P, Dudash MR, Thomson JD. Pollination syndromes and floral specialization. Annu. Rev. Ecol. Evol. Syst. 2004;35:375-403.
12. Flach M. Nutmeg cultivation and its sex problem. Meded. Landbouwhogeschool Wageningen. 1966;66(1):1-85.
13. George ST, Latha B, Mathew L, Geetha CK. Pattern of flowering and flower development in Kodampuli (*Garcinia cambogia* Desr). Indian Cocoa Arecanut & Spices J. 1992;16(2):68-70.
14. Giribabu D. Studies on propogation growth Pulp and Seed Physiology and Marketing Survey of Tamarindus Indica Linn. 2007.
15. Givnish TJ. Ecological constraints on the evolution of breeding systems in seed plants: dioecy and dispersal in gymnosperms. Evol. 1980;34(5):959-972.
16. Harder LD, Barrett SC. Pollen removal from tristylous *Pontederia cordata*: effects of anther position and pollinator specialization. Ecol. 1993;74(4):1059-1072.
17. Holland D, Hatib K, Bar-Ya'akov I, Yonay E, El Hadi FA. Shani-Yonay Pomegranate. Hort Science. 2007;42(3):710-711.
18. Jayesh KC, Kumar R. Crossability in pomegranate (*Punica granatum* L.). Indian J Horti. 2004;61(3):209-210.
19. Joseph J. Floral biology and variation in cinnamon. In: Vishveshwara, E. (Ed.), Proceedings of PLACROSYM – IV, Indian Society for Plantation Crops, 3-5 December 1981, Mysuru. 1981, 431-434
20. Krishnamoorthy B. Sex conversion in nutmeg. Spice

India. 2000;13:11-12.
21. Krishnamoorthy B, Rema J. Indian Cocoa Arecanut Spices J. 1994b;18:82-84.
22. Labandeira CC, Kvacek J, Mostovski MB. Pollination drops, pollen, and insect pollination of Mesozoic gymnosperms. Taxon. 2007;56(3):663-695.
23. McIlroy RJ. An introduction to tropical cash crops. Ibadan University Press, Ibadan, Nigeria. 1978.
24. McWilliam JR. The role of the micropyle in the pollination of Pinus. Bot. Gaz. 1958;120(2):109-117.
25. Mohankumar GN, *et al.* Indian Cocoa, Arecanut and Spices J. 1984;8:100-102
26. Momose K. Beetle pollination in tropical rain forests. In Pollination ecology and the rain forest. Springer, New York, NY. 2005, 104-110.
27. Momose K, Yumoto T, Nagamitsu T, Kato M, Nagamasu H, Sakai S, *et al.* Pollination biology in a lowland dipterocarp forest in Sarawak, Malaysia. I. Characteristics of the plant-pollinator community in a lowland dipterocarp forest. Am. J Bot. 1998;85(10):1477-1501.
28. Moncur MW, Mitchell A, Fripp Y, Kleinschmidt GJ. The role of honey bees (*Apis mellifera*) in eucalypt and acacia seed production areas. The Commw. For. Rev. 1995, 350-354.
29. Morton J. Pomegranate. In: Fruits of Warm Climates, Miami, FL. [on-line]. Available: www.hort.purdue.edu/newcrop/morton/pomegranate.htm [20 Oct 2019] 1987.
30. Mukherjee SK, Singh RN, Majumder PK, Sharma DK. Present position regarding breeding of mango (*Mangifera indica* L.) in India. Euphytica. 1968;17(3):462-467.
31. Nagarajan B, Nicodemus A, Mandal AK, Verma RK, Gireesan K, Mahadevan NP. Phenology and controlled pollination studies in Tamarind. Silvae Genetica. 1998;47(5):237-240.
32. Nath N, Randhawa GS. Studies on Floral Biology in the Pomegranate (*Punica Granatum* L.) I. Flowering Habit, Flowering Season, Bub Development and Sex-Ratio in Flowers. Indian J Hortic. 1959;16(2):61-68.
33. Nilsson LA. The evolution of flowers with deep corolla tubes. Nat. 1988;334(6178):147.
34. Opler PA, Bawa KS. Sex ratios in tropical forest trees. Evol. 1978;32(4):812-821.
35. Owens JN, Simpson SJ, Caron GE. The pollination mechanism of Engelmann spruce (*Picea engelmannii*). Can. J Bot. 1987;65(7):1439-1450.
36. Owens JN, Takaso T, Runions CJ. Pollination in conifers. Trends Plant Sci. 1998;3(12): 479-485.
37. Pool PA, Bermawie N. Procedure for artificial cross pollination in clove (*Syzygium aromaticum*). Euphytica. 1987;36(2):479-482.
38. Purseglove JW. Tropical crops. Dicotyledons 1 and 2. Trop. crops. Dicotyledons 1 and 2. 1968.
39. Ranga NR. Importance of pollination [on-line]. Available: https://www.studyread.com/importance-of-pollination/ [20 Oct.2019] 2019.
40. Shanmugavelu KG, Madhava Rao VN. Spices and Plantation Crops. Popular Book Deptt. Madras. 1977, 18-29.
41. Sharma MV, Shivanna KR. Pollinators, pollination efficiency and fruiting success in a wild nutmeg, *Myristica dactyloides*. J Trop. Ecol. 2011;27(4):405-412.
42. Spices Board. 1997. Spice catalogue [Online] Available: http://www.indianspices.com/spices-development/spice-catalogue [15 Oct 2019]
43. Subba R. A comparative survey of atmospheric pollen and fungus spores at two places twenty miles apart. Acta allergologica. 1970;25(2-3):189-215.
44. Surso M. Pollination and pollen germination in common juniper (*Juniperus communis*: Cupressaceae). Arctic Environ. Res. 2018;18:162.
45. Thangaselvabai T, Kennedy RR, Joshua JP, Jayasekar M. Clove (*Syzigium Aromaticum*) – The Spicy Flower Bud of Significance-A Review. Agric Rev. 2010;31(1):40-47.
46. Thangaselvabai T, Prem Joshua J, Jayasekar M. Cinnamon (*Cinnamomum verum* Presl)-the sweet bark spice for flavour and fragrance-a review. Agric. Rev. 2009;30(3):176-175.
47. Thimmaraju KR, Reddy MAN, Swamy N, Sulladmath UV. Studies on the floral biology of tamarind (*Tamarindus indica* L.) [tropical fruits India]. Mysore J Agric. Sci. 1977.
48. Tidbury GE. The clove tree. Crosby Lockwood and Son Ltd., London. 1949.
49. USDA [United State Department of Agriculture]. U S Forest Service, caring for the land and serving people. [Online]. Available: https://www.fs.fed.us/wildflowers/pollinators/What_is_Pollination/syndromes.shtml [15 Oct 2019] 2019.