Vanilla planifolia: history, botany and culture in Reunion island

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Review article

Vanilla planifolia: history, botany and culture in Réunion island

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Abstract – *Vanilla planifolia* is the only orchid of significant economic importance as an edible crop. The *Vanilla* genus contains about 110 species, all of them distributed between latitude 27° north and 27° south on all continents except Australia. Under natural conditions, *Vanilla planifolia* climbs, covers its support and flowers when it reaches the top of the canopy. In Réunion Island plantation conditions, vines are cultivated as a monoculture on several supports or in sugarcane interplanting culture. Agronomic fields, such as plantation and maintenance, diseases, flowering, pollination and regulation of fruiting are discussed in this review. (© 1999 Inra/Éditions scientifiques et médicales Elsevier SAS)

***Vanilla planifolia* / botany / growth / cultivation / flowering**

Résumé – La vanille histoire, botanique, culture à la réunion. *Vanilla planifolia* est la seule orchidée à avoir une importance économique significative en tant que denrée alimentaire. Le genre *Vanilla* comprend environ 110 espèces distribuées entre 27° de latitude Nord et 27° de latitude Sud sur tous les continents, à l'exception de l'Australie, En condition naturelle, les lianes de *Vanilla planifolia* grimpent le long de leur support et fleurissent lorsqu'elles ont atteint la canopée. Dans les plantations de l'île de la Réunion, les lianes sont cultivées soit en monoculture sur divers supports ou en association avec la canne a sucre. Certains points agronomiques comme les techniques de maintenance, les maladies, la floraison, la pollinisation et la régulation de la fructification du vanillier ont été ici discutés. (© 1999 Inra/Éditions scientifiques et médicales Elsevier SAS)

***Vanilla planifolia* / botanique / croissance / culture / floraison**

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Since the last important review by Bouriquet in 1954 [7], cultivation methods for vanilla plants have been modified, from extensive culture in Madagascar forests to an intensive culture in Réunion Island. Moreover, since 1956, very little has been published about *Vanilla* culture and exisiting data are dispersed and difficult to obtain. In the present article, we tried to update Bouriquet's review [7], discussing the *Vanilla planifolia* Andrews cultivation and focusing on the Réunion Island methods.

1. Economy

Vanilla planifolia Andrews is the only orchid of significant economic importance as an edible (i.e., condiment) crop. In 1992, major vanilla cultivating countries are Madagascar (700 tons), Indonesia (400 tons), Comoros Islands (150 tons), Réunion (12 tons), Mayotte (1 ton), Mauritius, Tonga, Tahiti (*Vanilla tahitiensis* JW Moore), and Mexico and China each produce less than 50 tons a year. The total annual production is 2 000 tons of vanilla beans estimated at US$ 120 000 000. The USA is the major consumer (1000 tons), followed by Europe (250 tons) and Japan (32 tons).

Vanilla provides the aroma in 50% of aromatic compounds and is the most widely used fragrance in perfume production. Because of the great demand, vanillin is also produced synthetically from wood, but the natural preparation is superior in flavour [5, 18, 28, 40, 41, 43, 52]. Still, synthetic vanillin production today is estimated to 12 000 tons.year^{-1} versus 20 tons.year^{-1} of natural vanillin.

2. Etymology

The word vanilla is an adaptation of the Spanish *vaynilla*, derived from *vaina* diminutive of the Latin *vagina* (case) [7]. The Franciscan Bernhardina de Sahagun perhaps wrote the first publication on vanilla in 1575, where he described the use of vanilla by Indians in Mexico. In 1602, Charles de L'Ecluse (1526–1609) wrote in Leyden the first botanical description of *Vanilla planifolia*. The Reverend Father Charles Plumier (1646–1704) used the generic term of *Vanilla* for the first time in 1703 in his study on Caribbean vanillas. Antoine Laurent de Jussieu (1748–1836) kept the generic term of vanilla in 1722, but Carl von Linné (1707–1778) used it as a specific epithet in his *Species plantarum*, referring to the species described by Plumier, as *Epidendron vanilla* [7].

Vanilla planifolia was described in 1808 by Henry C. Andrews (?–1830), but this binomial denomination was abandoned and *Vanilla fragans* (Salisb.), proposed by Oakes Ames (1874–1950), was adopted in 1924 [38]. However *Vanilla planifolia* has priority [27, 30] and should be restored. *Vanilla* has also been called the following: *Lobus aromaticus*, *Volubilis siliquos mexicana*, *Vanilla mexicana*, *Vanilla epidendrum*, *Vanilla viridiflora*, *Vanilla sativa*, *Vanilla sylvestris*, and *Vanilla fragans* ([32] in which authors name were not cited).

3. Botany

The *Vanilla* plants are all terrestrial, climbing and although they do not branch or branch poorly in the shade, they do so when the vines are exposed to the sun [27]. The taxonomic position of the genus *Vanilla* is presented in *table I*. *Vanilla* genus contains about 110 species (*table II*), all of them being distributed between latitude 27° north and 27° south on all continents except Australia [38].

4. History of vanilla dispersion

Vanilla planifolia was brought into Europe through Cadiz (Spain) in 1721. Antoine de Jussieu [29] gave a presentation on vanilla to the Académie des Sciences de Paris in 1722. Mr. Partiet, the french consul in Cadiz, presented several parts of this communication. The diplomat wrote a short memorandum after obtaining infor-

Table I. Classification of *Vanilla* genus according to R. Portères [38].

Family	*Orchidaceae*	
Sub-Family	*Orchidoideae*	Only one fertile stamen and two staminods.
Section	*Acrotoneae*	Anther more or less deciduous with straight point of junction; column with a dimple between the anther point of junction and the rostellum. Epiphytic or terrestrial plant. Friable pollinia.
Tribe	*Neottieae* (*Polychondrae*)	All terrestrial plants.
Subtribe	*Vanillae*	
Genus	*Vanilla*	

mation from Father Fray Ignatio de Santa Theresa de Jesus who cultivated vanilla plants in Cadiz.

In 1739, the most clearly substantiated introduction of vanilla into Europe was by an English gardener, Philip Miller (1691–1771), but his attempt to cultivate the plant failed. The Duke of Marlborough made another introduction of vanilla into the collection of the Honourable Charles Greville at Paddington Garden and the plant bloomed. Most likely, vanilla spread from England to the European continent. In 1912, Henry Nicholas Ridley (1855–1956) suggested that in 1812 [42], vanilla be sent from H.C. Greville's gardens to Joseph J. Parmentier (1755–1852) of Enghien (Belgium), who introduced the plant at Antwerp (Belgium) where it was put under to the care of director of the Antwerp botanic garden.

Charles Morren (1807–1858) gave some cuttings of the plant cultivated in Antwerp to the Botanical Gardens of Paris (France) and Liège in Belgium (1839). However, it is not possible to date the introduction of vanilla in Paris, despite a research of the French Record Office (Archives Nationales), where the reports of all museum professors are kept. It seems that André Trouin (1747–1824) introduced vanilla in Paris. In January 1945, lack of heating resulted in the destruction of all plants in the museum greenhouses.

Captain Pierre Henri Philibert, introduced *Vanilla pompona Sch.* into Réunion, from French Guyana [14]. In 1821, Mr Marchant introduced *Vanilla planifolia* from the Paris Botanical Gardens to Réunion where it grew successfully.

In 1819, Elie Marchal (1839–1923) sent *Vanilla planifolia* to the Dutch colonies of Java [7, 34]. Admiral Hamelin brought *Vanilla planifolia* from Manilla to Tahiti in 1848 and Admiral Bonard introduced *Vanilla planifolia* in Réunion Island during the same period. Afterwards, vanilla was introduced into Gabon (1873), New Caledonia (1861) and Vietnam (1865). From Réunion, vanilla was taken to the Seychelles Islands (1861), Comoros Islands, Mayotte (1873) and Mauritius (1880). Vanilla was introduced into Puerto-Rico before 1900 and completed by the US Department of Agriculture in 1909, using plants from Mexico and Florida. [7].

5. Ecology

5.1. Climate

Vanilla planifolia originates from the Mexican tropical rain forest. Its cultivation requires the same climatic conditions. The temperatures should be between 20 and 30 °C. Nevertheless, plants could accept a maximum about 33 °C and a minimum not lower than 10 °C. Rainfall must be evenly distributed, with a minimum of 2 000 mm.year^{-1} [7, 45–47].

Table II. List of *Vanilla* species classified according to R. Portères [38].

Section: *Foliosae* - Sub-section: *Papillosae*		
V. *angustipetala* Schl.	V. *griffithii* Reichb. f.	V. *piliferia* Holttum
V. *anomala* Ames et Will	V. *hostmanni* Rolfe	V. *ponapensis* Kanch. et Yam.
V. *argentina* Hick.	V. *imperialis* Kraenzl.	V. *preussii* Kraenzl.
V. *chalotii* Fin.	V. *lindmaniana* Kraenzl.	V. *riberoi* Hoelne
V. *coursii* H. Perr. B.	V. *lujae* De Wild	V. *ronoensis* Hay.
V. *duckei* Huber	V. *moonii* Thw.	V. *somai* Hay.
V. *françoisii* H. Perr. B.	V. *nigerica* Rendl.	V. *tisserantii* Port.
V. *gardneri* Rolfe	V. *ovalis* Blanco	V. *vellozii* Rolfe.
V. *grandifolia* Lindl.	V. *palembanica* Teys. et Binn.	V. *verrucosa* Haum.
Section: *Foliosae* - Sub-section: *Lamellosae*		
V. *abundiflora* J.J. Sm.	V. *hamata* Klotz	V. *planifolia* Andrews
V. *acuminata* Rolfe	V. *hartii* Rolfe	V. *polylepsis* Summerh.
V. *africana* Lindl.	V. *havilandii* Rolfe	V. *pompona* Sch.
V. *albida* Blume	V. *heterolopha* Summerh.	V. *ramificans* J.J. Sm.
V. *bicolor* Lindl.	V. *insignis* Ames	V. *ramosa* Rolfe
V. *borneensis* Rolfe	V. *kaniensis* Schl.	V. *ruiziana* Klotz
V. *calyculata* Schlech.	V. *kinabaluensis* Carr.	V. *seranica* J.J. Sm.
V. *carinata* Rolfe	V. *klabatensis* Schl.	V. *sereti* De Wild
V. *chamissonis* Klotz	V. *leprieurii* Port.	V. *siamensis* Rolfe
V. *columbiana* Rolfe	V. *marowynensis* Pulle	V. *sprucei* Rolfe
V. *crenulata* Rolfe	V. *montana* Ridl.	V. *sumatrana* J.J. Sm.
V. *cucullata* Kraenzl.	V. *odorata* Presl.	V. *tahitiensis* JW Moore
V. *ensifolia* Rolfe	V. *phaeantha* Reichb.f	V. *wariensis* Schl.
V. *fimbriata* Rolfe	V. *pierrei* Gagnp.	V. *zanzibarica* Rolfe
V. giulianettii F.M.	V. *pittierii* Schl.	
Section: *Foliosae* - Sub-section: *Membranaceae*		
V. *acuta* Rolfe	V. *organensis* Rolfe	V. *pfaviana* Reichb. f.
V. *bertoniensis* Bert.	V. *ovata* Rolfe	V. *pleei* Port.
V. *bradel* Schl.	V. *palmarum* Lindl.	V. *weberbaueriana* Kraenzl
V. *inodora* Sch.	V. *parvifolia* Barb.Rodr.	V. *wrightii* Reichb.
V. latisegmenta Ames et Schw.	V. *perexilis* Bertoni	
Section: *Aphyllae*		
V. *aphylla* Blume	V. *dilloniana* Correl.	V. *perrieri* Schl.
V. *barbellata* Reichb.f.	V. *egersii* Rolfe	V. *phalaenopsis* Reichb.f.
V. *bekeri* Schl.	V. *humboltii* Reich.	V. *poitaei* Reichb.f.
V. *calopogom* Reichb.f.	V. *madagascariensis* Rolfe	V. *roscheri* Reichb.f.
V. *claviculata* Sw.	V. *montagnacii* R. Port.	V. *walkeriae* Wight
V. *decaryana* H. Perr. B.	V. *parishii* Reichb.f.	V. *wightiana* Lindl.

Vanilla, being a forest climber, requires moderate shade. However, excessive shade can be deleterious: the vine become thin and susceptible to diseases (mildew and root rot) and yields drop [9, 13].

5.2. Soils

Vanilla culture is a horticultural rather than an agricultural practice. An ideal soil for vanilla is light, rich in humus [47] and porous, allowing the roots to spread without encountering high moisture. However, vanilla can grow in many types of soils, if they are not heavy and have good drainage. Volcanic soils, sand and laterites are also suitable. Vanilla does not have large mineral nutrition requirement, and even a plant which produces 1 kg of beans a year uses only 1 or 2 g of mineral elements [31, 47].

6. Growth of vanilla under natural conditions

Under natural conditions, a vanilla plant climbs, cover its support, and flowers when it reaches the top of the canopy, 15–20 m high. Seed germination is rarely observed in the forest, but it is possible to see young vines developing from fragments that fall on the forest floor. These thin vines never flower, creep along on the floor until they encounter a support onto which they cling and climb to the canopy, where the light intensity is appropriate. Vines attach to the support with adventitious (or aerial) roots. One or two aerial roots develop from a node on the side that is in contact with the phorophyte. These roots are glabrous, non-branched and have a dorsiventral organization. Their root hairs secrete amorphous cement, which glues them to the phorophyte [39]. Their length is 0.05–15 cm. The roots have a short life span (1–2 years). These aerial roots are not replaced after death.

At the base of the vine, terrestrial roots take up nutrients from the soil. These roots are branched, have well-developed root hairs and velamen cells [39]. Their length varies and depends only on the distance between the vine and the substratum. When terrestrial roots die, they are replaced quickly by new ones. The new roots originate either at the same node or on another node. The vine may 'zigzag' and form a 120° angle between internodes (*figure 1*). This angle increases with age and when the vine detaches from its support. If a large vine becomes detached from its support, it breaks and falls on the forest floor where it can root. During growth, stem diameter increases with plant length. The diameter of the base increases with time (i.e., plant age) and is smaller into shade than in sunlight. During growth on the porophyte, winds frequently destroy the apex of the vanilla plant. The branching resulting from vanilla plant apex decapitation (due to mechanic damages, wind, etc.) presents nodes with a larger diameter than the internode from which it arises (*figure 1*). Indeed, the diameter value is important, for when it reaches 6 to 13 mm, the vine can flower. There is a threshold diameter for flowering: if the diameter of a stem is less than 6 mm, vanilla does not flower [15].

Under natural conditions, inflorescences can be found at a minimum of 20 nodes below the apex. If the apex is removed, inflorescences appear on the second or the third node below the decapitation and a new shoot arise from the first one.

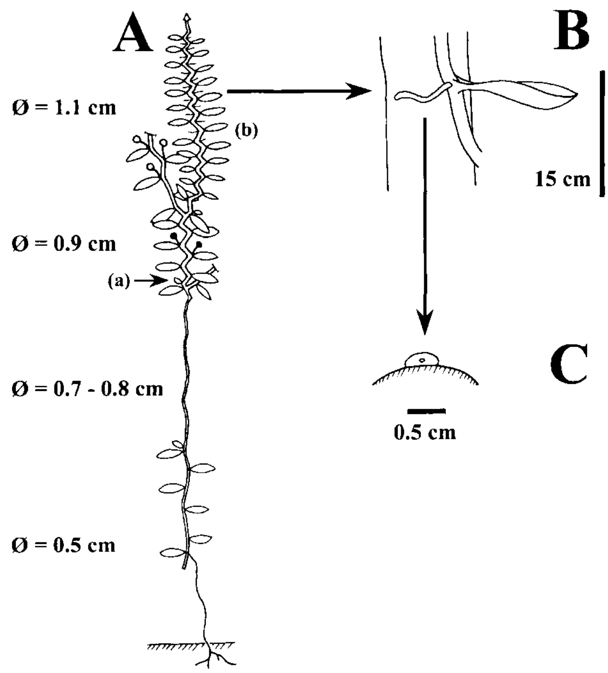

Figure 1. A. B. C. Diagrammatic representation of a *Vanilla* plant under natural conditions. A. Whole plant (○, current year inflorescence; ●, last year inflorescence) with stem diameter along the vine. B. Detail of the vine on support showing one leaf and one adventitious root inserted at the node level. C. Transverse cross-section of adventitious root on the support.

This new branch can fall if it encounters no support. Should this happen, there are two possible outcomes: the vine can break, fall and act as a cutting, which produces a new shoot or when the apex is not broken, the vine continues to grow in length. If it does not encounter a support immediately, it creeps until it reaches one. Thus, several independent vines may grow on one support.

Leaves of young vines are small, narrow, and last 3–4 years.

Vanilla planifolia is a monopodial orchid. Its apex has the potential for indefinite growth if it is not damaged. The distribution of inflorescences in vanilla is strongly associated with the architecture of the plant and is expressed in accordance with precise morphogenetic gradients. Apex degeneration or decapitation that favor the appearance of new branch (es) can affect these gradients [15].

7. Vanilla plantations

7.1. Culture under trees

This is the most widely used method in the world. Cuttings are planted at the base of existing forest tree supports and the vine climbs on them. Planting density in such plantations varies from 3 000 to 4 000 plants.hectare^{-1}.

7.2. Mono culture

Plantations consist of vanilla plants on supports only. The density is 4 000 plants.hectare^{-1}. Distances between plants are 1.20 m and 1.70 m between rows. The principal phorophytes are *Dracaena reflexa* var. *marginata*, or *Jatropha curcas*.

7.3. Sugar-cane inter-planting culture

This intensive culture method has been used in Réunion for 35 years. Both sugar cane and vanilla are planted at the same time. Production in such plantation is high because sugar cane provides ideal shade which can be regulated easily, serves as a windbreak, remnants, such as leaves, decompose slowly and provide organic and mineral nutrients for the vanilla. Cultivated in association with vanilla (50% sugar cane, 50% vanilla) sugar cane grows as rapidly as in single culture. During the first four years, sugar cane production increases by a factor of 1.3 or 1.5 depending on variety and region.

Sugar cane grows well during the first three years and creates good conditions (shade, moisture) for the vanilla. Losses are largely compensated by vanilla production. Sugar cane in such plantations must be cut four months before the vanilla flowers [13].

The most commonly used vanilla support is *Dracaena reflexa* var. *marginata*. Several modes of sugar cane interplanting culture are used depending on degree of mechanization of the sugar cane. Density is 2500 vanilla.hectares^{-1}. Examples are:

Alternants row of vanilla and sugar cane. The distances are 1.20 m between vanilla plants and 1.70 m between rows.

Two rows of vanilla and two rows of sugar cane. The distances are 1.20 m between vanilla plants in the rows, 1.20 m between vanilla rows and 1.70 m between vanilla rows and sugar cane rows [13].

The combination vanilla – sugar cane is optimal because the work is easy, the shade is appropriate, harvesting can be mechanized easily and air circulation is good and reduces the relative humidity [13].

8. Plantation management and maintenance

8.1. Clearing

In Réunion, soils are rocky. Clearing is used mainly for vanilla monoculture or sugarcane interplanting culture plantations. Land must be cleared to allow for the mechanization of operations such as spreading of chemical fertilisers, weeding, cutting and collecting the sugar cane. Rocks are placed in rows at the field borders. Nevertheless, such clearing may damage the soil by reducing humus levels leading to fertility loses.

8.2. Supports

The supports can be planted six months before the vanilla, but one year is preferable to favor the root implantation and vegetative development. In Réunion, plantations are started at the beginning of the rainy season. An appropriate support must have the following properties: wind resistance (frequent hurricanes); disease resistance; easy and infrequent pruning; good recovery after cutting; a deep root system that does not compete with the vanilla roots.

In Réunion, *Dracaena* is used for support. Cutting are 1.50 tall and a hormone preparation like Rootone is used to accelerate root formation.

In pure groves, it is difficult to obtain proper shade during the first year. Therefore, it is recommended to interspace with manioc (*Manihot esculenta*) and *Dracaena*. [13].

8.3. Vanilla cuttings

The choice of vanilla cuttings is very important because it determines the future development of the vine. Following the selection of a location for a new plantation and the culture method, it is necessary to obtain good cuttings. A good vanilla cutting must adapt quickly to local conditions, come from a healthy and vigorous mother plant, have an intact apex, and must be 1.20 to 1.50 m (12–15 nodes) long [13].

Aerial roots must be removed from the cuttings, which should be allowed to wilt, hanging under shade for 15 days. Injuries due to cutting and heal should be avoided during this period.

The basal three nodes should be inserted into the soil. Roots and new growths are formed within one or two months after planting. Such plants produce vigorous branches. Most of vines produce flowers during the fourth year, but some may flower earlier. Such a vanilla grove can produce for 10–12 years.

8.4. Mulching

In sugarcane interplantation, the old foliage from the cane provides abundant and frequent mulch. All dry cut products are collected at the foot of the vanilla plant. As the mulch decomposes, it provides humus. Mulching is important to keep water and nutrients close to the vanilla roots, to prevent weeds from growing and to protect the soil and vanilla roots from overheating [13].

8.5. Weeding

Weeds usually do not grow in mulched vanilla rows. When present, weeds can be eliminated with lawn mower (with rotating nylon string) or a herbicide (*table III* [12]). Care should be taken not to damage the roots.

The vanilla plants should be protected during herbicide application. If not applied properly, herbicides can kill vanilla shoots or delay development. Gramoxone (Paraquat) or 2,4-dichlorophenoxy acetic acid applied during flowering can induce the formation of poor quality parthenocarpic fruit [26].

Table III. Herbicide treatments for *Vanilla* plantations [12].

Commercial name	Active substance	Concentration	Activity
Roundup®	Glyphosate	4 kg.Ha^{-1}	2 months
Primextra®	Metachlor+Atrazine	6.1 kg. Ha^{-1}	3 months

8.6. Fertilisation

Mulch provides nutrients. Chemical fertilizers are not needed and are not recommended. Manure is also not recommended. Only fresh soil should be added from time to time.

8.7. 'Looping', training and pruning.

When vanilla cuttings are planted in soil, their upper parts should be bent as a curve. Shoots begin to develop at the level of the curvature (*figure 2A*). These shoots climb on the support. When a new shoot reaches a length of 2 m, it should be 'looped'. This consists of carefully (the vines are very fragile) detaching the upper part of a long shoot (20–25 nodes) from the support. The vine has to be bent over the support at an appropriate height in the way that the extremity of the stem is placed near the soil. Leaves near the soil must be cut to prevent fungal attack and the upper part of the vine is attached to the support. The shoots should be placed so that the upper leaf surfaces are orientated towards the sunlight (*figure 2B*). Looping is an important operation because it allows formation of new roots and shoots, and therefore good growth.

Whenever a shoot is bent, one or more previously dormant axillary buds become active and give rise to new vegetative shoots. Once these are sufficiently long, the vine can be detached from the support and looped again. This should be repeated with all new shoots. After three or four years, the original vanilla cutting gives rise to a plant composed of many shoots that give the plant a so-called 'tuft' appearance (*figure 2C*). When the plant is looped, all dead parts and unproductive shoots should be removed to clean the tuft. After proper cleaning, a tuft consist of vegetative parts not exceeding 5–6 years in age.

Three months before flowering, training the vines is necessary. This consists in detaching a new

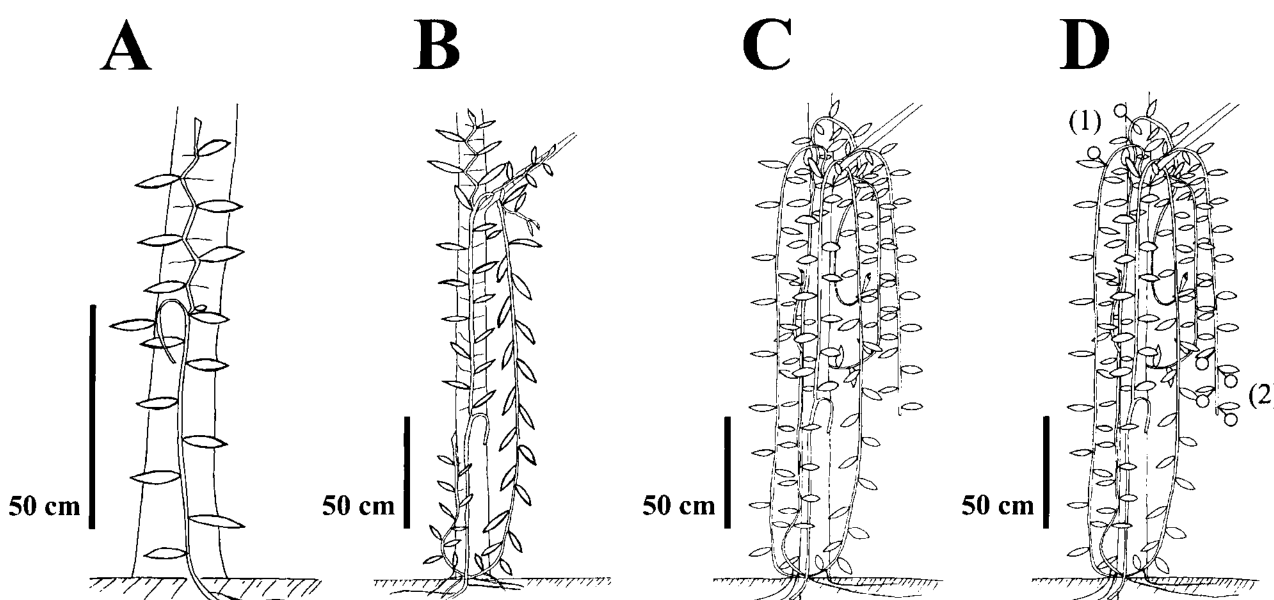

Figure 2. A. B. C. D. Looping, training, pruning and flowering of *Vanilla* cutting. A. Cutting with the upper part bent as a curve with an axillary shoot below the curvature. B. Looping, first stage. C. Pruning the upper part of the vine produces a training-vine that flowers. D. Flowering at the curvatures (1) and at the extremities (2) of the vine (○, inflorescence).

shoot (20–25 nodes) carefully and allowing it to hang over a support. The tips of the now pendulous shoot may be removed under the third node from the top (apex + 3 nodes). This very important operation can make the difference between a poor and a good production. In fact, these vines bear 2/3 of the crop. Decapitation may happen naturally (by the sun or wind), but is generally done on purpose by man.

In case of natural pruning, the probability of finding an inflorescence on the first node following the decapitation is 9%, 30% on the third node and 5% on the 20th node. With intentional pruning (human action), there is a 45% of chance for an inflorescence to develop on the first node. The chance that inflorescence will form on the 20th node is 5% [15]. Decapitation changes substantially the flowering of vanilla. It has been possible to estimate the production of inflorescences [15]: 2 268 inflorescences have been produced following sun pruning on 1000 vines, 3 255 inflorescences have been produced following mechanical pruning on 1000 vines.

The increase of 44% is indeed significant leading to an estimated crop of 1 ton.hectare^{-1}.

9. Flowering, pollination and regulation of fruiting

9.1. Flowering

Flowering times of vanilla vary with the world region (*table IV*). Generally, the first flowers vanilla appear 2–3 months following the third year after planting. Each plant blooms for one month. Each inflorescence has only a single flower open at any one time and a flower lasts only one day.

A vanilla plant bears 10–12 inflorescences by tuft and by year or even more if it is very vigorous.

9.2. Enhancement of flowering

Orchid flowering has been studied by a number of researchers. *Phalaenopsis*, *Cattleya*, *Cymbidium*, *Vanda*, *Odontoglossum* and *Aranda* were studied most extensively because they respond to definite stimuli.

Sympodial orchids (*Cattleya*, *Dendrobium*, *Cymbidium*) are generally induced to flower by thermoperiods and photoperiods [1, 2, 3, 25], which may affect changes in endogenous hormone concentrations [17, 22].

Several monopodial orchids respond to photoperiods [6, 13, 38, 39, 44, 50]. Pruning may also have an effect [19, 23]. Several growth regulators were used with success [4, 8, 20, 21, 22, 24, 25, 35].

Only pruning, as human mechanic action, seems to enhance vanilla flowering [31]. Nevertheless, early experiments showed that light intensity might also play an important role in the flowering of vanilla. Indeed, sunny plantations such as those done with sugarcane produce more flowers than those done in forest. In Réunion, it is assumed that flowers are induced in June. Days are short, but the light intensity is high. During this period, illumination is an important factor. The correlation between light intensity in June and production is high ($r = 0.93$). A good correlation ($r = 0.72$) also exists between the light intensity in July and production [15].

It is not known at present if day length plays an important role in flower induction in vanilla. However, it is possible that in Réunion, a primary factor may be short-days or low night temperatures in June or a combination of both. These stimuli are known to induce flowering in other orchids [25]. A

Table IV. Flowering times of *Vanilla* depending to the word region [7].

Place	Flowering period
French Antilles	February-March
Comoros	October-December
Indonesia	June-September
Madagascar	November-January
Puerto-Rico	January-April
Réunion Island	October-December
Tahiti	October-January

correlation between vanilla production levels and temperatures or precipitation does not seem to exist [15].

Several growth regulators (alone or in combination) have been tested for their ability to induce flowering in vanilla. They include triazole (anti-gibberelic acid), Dormex®, Cycocel®, Ethephon®, maleic hydrazide (anti-auxin), Rootone F®, gibberellic acid, benzyladenine, triiodobenzoic acid (TIBA) and paclobutrazol (*table V*). Results on flowering have not been positive. Some treatments brought about an increase in the number of inflorescences, but they were accompanied by deformation of leaves, flowers and fruits as for example when triazole was used. We also noted that vanilla plants die after ethrel (Ethephon®) sprays [15].

In Réunion, soils are deficient in boron and zinc [15], which are applied to vanilla in foliar sprays (*table VI*). In shaded culture, the treatment had a good effect on flowering. However, the effect was not statistically significant on mixed vanilla – sugarcane interplantings. In cloudy years, when light condition was poor inflorescence production by treated plants could be 50% higher than by the non-treated ones. This suggests that the effects of boron and zinc are beneficial under low light [27].

9.3. Pollination

In Mexico, where vanilla is native, a specific pollinator, a small stingless *Melipona* bee, pollinates the flowers. However, only 1% of all flowers are pollinated this way [7].

Two artificial pollination methods can be used to increase fruit production. One method uses auxin 2, 4 dichlorophenoxy acetic acid (2, 4-D) and results in few, small parthenocarpic fruit [26]. Such fruits do not produce an aroma and this technique has now been abandoned. The second method involves hand pollination. Discovered in 1836 by Charles Morren [33], the technique was improved in Réunion and brought into routine use in 1841 by Edmond Albius [5, 7, 32].

The Morren technique [33] consists of removing the pollinia with a needle and inserting them between the rostellum and the stigma. This method is still in use to pollinate vanilla in Tahiti. It is also employed for ornamental orchids. However, it is

Table V. Growth regulators and others chemicals tested on *Vanilla* [15]. Foliar spray, 500 $l.Ha^{-1}$.

Commercial preparative	Chemical Name	Effects
	1-phenoxy-5.5-dimethyl-3-(1.2.4-triazol-1-yl) -hexan-5-ol (TRIAZOL)	Deformations of leaves, stem, flowers and fruits. Antigibberellic effect
Berelex®	gibberellic acid (GA3, 92%)	No effect
Ethephon®	(2-chloroethyl)phosphonic acid (ETHEL)	Death of plants
Rootone F®	naphthaleneacetic acid + triiodobenzoic acid	No effect
Parlay C®	ß-[(4-chlorophenyl)methyl]-a-(1.1 -dimethylethyl)-1*H*-1,2,4-triazol-1-yl)pentan-3-ol (PACLOBUTRAZOL) + 2-chloro-*N,N,N*-trimethylethanaminium chlorid (CHLORMEQUAT CHLORIDE)	Deformations of leaves, stem, flowers and fruits. Antigibberellic effect.
Benzyl adenine	N-(phenylmethyl)-1*H*-purine-6-amine	No effect
Cycocel ® C5	CHLORMEQUAT CHLORIDE + CHOLINE CHLORID	No effect
Dormex®	hydrogen cyanimide	Death of plants
	Maleic hydrazide	Small effect on the flowering but no statistically significant

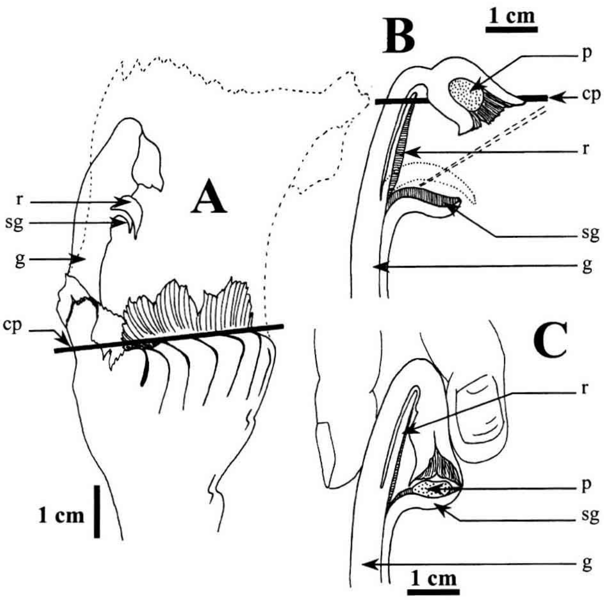

Figure 3. A. B. C. The Albius method for *Vanilla* pollination. A. First step, the labellum is pulled down with a needle (cactus spine; cp) to the base of the flower to free the gynstemium (g), rostellum (r), stigma (sg) and pollinia (p). B. The needle is then introduced underneath the rostellum pushing it to the base of the anther, uncovering the stigma. C. In the last step, the anther is held between the thumb and the index finger and pressed gently onto the stigma in such a way that the pollinia stick to the stigma.

slow and difficult to carry out. Albius simplified the process and converted it into a fast and efficient process.

The original or Albius method is by far the most widely used procedure in Réunion. First, the labellum is pulled down with a needle (cactus pine; cp) to the base of the flower (*figure 3A*) to free the gynstemium (g), rostellum (r) and pollinia (p). The needle is then placed below the rostellum pushing it toward the base of the anther (*figure 3B*), uncovering the stigma (sg). In the last step (*figure 3C*), the anther is held between the thumb and the index finger and pressed gently onto the stigma causing the pollinia to stick to it.

The tearing technique is a slight modification of the Albius method. It differs in that the labellum is torn away and collected by workers so that the number of pollinated flowers can be recorded (*figure 4 A, B*). Pollination is facilitated through the exposure of the sexual part. The tearing technique method is used in Madagascar to evaluate production and to count the number of pollinated flowers.

Pollination must be carried from dawn until not long after noon and the outcome is strongly dependent on climatic and human factors. For example, success is highest during sunny days. An experienced worker can carry out between 1500–2 000 pollinations per day [16].

9.4. Regulation of fruiting

The ovary develops after pollination. After 5–6 weeks, it reaches full size development. All unpol-

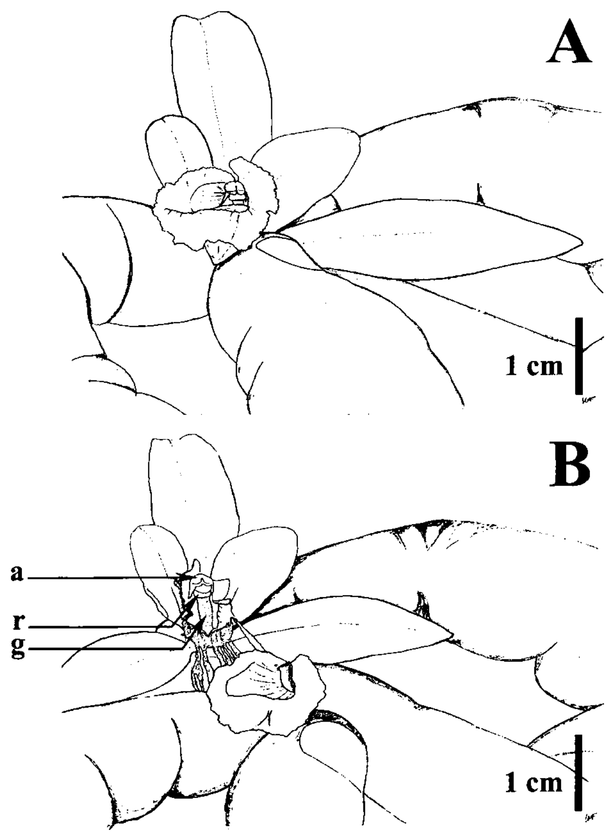

Figure 4. A. B. The tearing technique for *Vanilla* pollination. A. The labellum is torn away and collected. B. Manual pollination is facilitated trough the exposure of the sexual part: a, anther; r, rostellum; g, gynostemium.

Table VI. Effect of boron and zinc applied as leaves spray on flowering of *Vanilla* [15].

Type of *Vanilla* Plantation	Number of inflorescences Not treated	Treated
Sugar cane interplanting	10.9 ± 8.61	11.4 ± 5.34
In shade, in soil	4.14 ± 2.23	8.83 ± 1.97
In shade, in volcanic soil	2.70 ± 2.02	4.14 ± 1.61

linated flowers and fruits, which are small or deformed, are removed after one month. B. Swamy [48] describes ovary development.

To ensure normal fruit size, no more than 10 capsules should be allowed to develop on the same inflorescence. Considering that a capsule, measuring 24 to 28 cm, weight about 150 g, a 5-year-old *Vanilla* plant producing five inflorescences composed of six fruits may produce an harvest weightting about 4.5 kg capsule per plant. Nevertheless a reasonable estimation has to consider that 50–70% of all fruits abscises since one week to two months after pollination.

9.5. Harvest

Fruits mature eight to nine months after pollination. If harvested before maturation capsules have reduced aroma after post-harvest treatment and may deteriorate. If harvested too late, the capsules split. The best stage for harvesting the 'beans' is the so-called 'canary-tail' ('queue de serin'). At this stage, the fruit is green, but its base is canary-yellow. Harvesting at this stage is a requisite for producing 'vanilla beans' of high quality and with good aroma. Capsules are harvested one at a time as they mature.

At harvest time, the capsules do not have any aroma. The aroma forms only after a long process [5, 7, 14, 32, 49] that spans nine months, during which the green capsules become black 'vanilla beans'.

10. Diseases

Snails, insects and birds eat young shoots or flower buds causing bud malformation and damaging to aerial roots. But fungal diseases cause the worst problems.

10.1. The vanilla root rot

The vanilla root rot could be due to different fungi: *Phytophthora jatrophae*, *Fusarium oxysporum* or *Fusarium vanillae* var. *bulbigenum*. The symptoms could be described as follows. During early stages shallow roots turn brown and die, The damage is generally not perceptible at first and vanilla plants can survive without showing symptoms. New roots may form, but they become infected as soon as they touch the soil. As a result, the plant cannot obtain water, minerals and turns yellow. The leaves become pendulous and abscise. At the end vines become flaccid and die.

In order to control this problem, some cautions have to be done. The disease is systemic and can be transmitted by tools, so tools must be disinfected. Uninfected cuttings must be used. Pollination should be limited to strong vines, particularly at first blooming. Looping should be regular. All dis-

Table VII. Fungicides used against *Vanilla* root rot [10].

Commercial name	Active substance	Concentration	Treatment
Aliette®	Phosetyl-Aluminium	2.5 $g.l^{-1}$	Preventive, one treatment before blooming
Bavistine®	Carbendazime	500 ppm	Preventive, one treatment before blooming
Sportak®	Prochloraze	500 ppm	Curative

eased parts must be removed and burned. Damaged root should be removed. Moreover, use of resistant cultivars would be the best solution and fungicidal sprays can also be used (*table VII*).

10.2. Vanilla mildew

Phytophthora jatrophae is responsive of vanilla mildew. The *Phytophthora* attacks roots and infects aerial parts. It causes black areas on vines. Fruit bases are also infected. The black areas produce a strong putrid odor.

To prevent the disease, it is important to observe the plants regularly, because early detection and treatment are important. Treatments should be applied before blooming. Infection risks are high during both the hot and the wet season.

Chemical substances can also be used (*table VIII*). *Jatropha curcas* should not be used for support because it is a preferential host for mildew.

10.3. Virus

Virus diseases appeared in French Polynesia [54], in Kingdom of Tonga [36, 37], and Mauritius ([11], J. Dequaire, 1989, personal communication). In Réunion, the virus was detected in 1989 (J. Albouy, 1989, personal communication). The disease may have been imported into French Polynesia on ornamental orchids [36, 37, 53, 54].

The casual agents of these diseases could be *Cymbidium* mosaic virus (CyMV), *Odontoglossum* Ringspot virus (ORSV) or vanilla potyvirus (VPV). The symptoms are chlorotic patches appearing on the foliage and the leaves are small and curved. Moreover, infected vines grow more slowly than healthy plant. The mode of transmission of CyMV is unknown; ORSV is transmitted by tools and VPV by aphids.

11. Perspectives

The botanical and agronomic approaches permit the understanding of this particular orchid: *Vanilla planifolia*. The yield amelioration is given by increasing the number of inflorescences. However, this control of the vegetative and floral development is not yet achieved. Mineral nutrition, fruit drop, diseases and selection of resistant plants will be the subjects of future investigations. Agronomic studies must be completed. Increase the number of flower and the level of transformation flower ovary into fruit after pollination is the most important point for productivity increase. Indeed, only 30 to 50 fruits will be harvested from 100 fecundated flowers. The causes of this lost are not explained. So, future work must involve studies linked to this important problem. The lost of well developed fruit, due to complication during the first sages in the formation of the capsules, may be linked to wrong fecundation, physiological stress, diseases or something else. Moreover, new approaches using molecular biology techniques could be operated. Indeed, the genetic diversity of *Vanilla* gender has to be prospected to determine the genetic stock available for future agronomic use.

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Table VIII. Treatments used against *Vanilla* mildew [10].

Commercial name	Active substance	Concentration	Treatment
Acylon®	Metalaxyl + Folpel	3 mL.L^{-1}	Preventive
Anteor C®	Cymoxanil + Folpel + Cu	6 g.L^{-1}	Preventive, spray every 15–20 days during the rain season
Aliette®	Phosetyl-Aluminium	2.5 g.L^{-1}	Curative, spray any 15–20 days

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