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Pilot scale cultivation and production of *Vanilla planifolia* in the United Arab Emirates

Khalil Ur Rahman[1*], Mohamed Khalifa Bin Thaleth[1], George Mathew Kutty[1], Ramachandran Subramanian[2*]

[1]*Al Nakhli Management, Dubai Hatta Road, Dubai, United Arab Emirates*
[2]*Birla Institute of Technology and Science, Department of Biotechnology, Pilani, Dubai campus, PO Box 345055, Dubai, United Arab Emirates*
[*]*Correspondence author:* khalill.rahman@hhpo.ae, sramachandran@dubai.bits-pilani.ac.in

Abstract

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Vanilla planifolia is cultivated in the tropical climate and primarily grown in Madagascar, Indonesia, China and Mexico. Pilot-scale cultivation of *V. planifolia* was trialed under greenhouse conditions in the United Arab Emirates. *V. planifolia* cuttings were obtained from India and it was grown through vegetative propagation. The cuttings of 50 cm long were planted in the soil-compost substrate at 4:1 ratio and irrigated with freshwater (water salinity 263 µS/cm). Every three months plant-based compost was added at a rate of 4 kg m^{-2}. The height of the vanilla plant was maintained at 1.5 m and vines were supported by galvanized pipes covered by ropes. The manual pollination method was carried out upon blooming. Pods were harvested manually when the tip turned light brown. Mature pods were graded, blanched, dried and packaged. 20 kg fresh pods obtained from the ten vanilla plants produced 4 kg processed and dried pods after curing by blanching and drying. *V. planifolia* production method reported under the controlled environment can be adopted to cultivate vanilla in other parts of UAE and GCC nations.

Keywords: vanilla; vanillin; sub-tropical environment; crop diversification

Introduction

Vanilla planifolia, known colloquially as 'vanilla vine', 'vanilla orchid' or and most frequently as vanilla. The word vanilla originates from the Spanish name vainilla, which translates to "little pod" which refers to the long and slender fruit.Vanilla is the world's third most expensive spice after saffron and cardamom as its cultivation is labor intensive which gives rise to the product's market to be highly volatile (Parthasarathy et al., 2008). The specific epithet 'planifolia', indicates the flat shape of the leaves of the plant. The common name of the flowering plant was established in 1808 by Andrews (Gabriel et al., 1999). It is a perennial orchid creeper with a thick, tubular and succulent green stem that requires tree trunks or other supports such as wooden stakes for its sustenance and flourish to an elevation of 10 to 15 meters (Janarthanam & Seshadri, 2008). Its extract is popularly used to impart its distinct aroma in desserts and to reduce required sweetener quantities (Berenstein, 2016).

Madagascar, Indonesia, China and Mexico are the primary producers of natural vanilla beans (Baqueiro and Guerrero, 2017). Natural vanillin is extracted from the seed pods of vanilla. Following harvest, the flavor is developed by the curing process to release the vanillin as a free molecule from vanilla beans. The pods are dried and further aged for several months during which time their flavors develop further. The vanillin is primarily used in food, cosmetics, perfume industries and to treat intestinal gas and fever (Abebe et al., 2009;

Chandran & Puthur, 2009; Retheesh & Bhat, 2011; Palama et al., 2011). Vanillin, vanillic acid, 4-hydroxybenzaldehyde and 4-hydroxybenzoic acid make up the major chemical components of these pods. Though vanillin can be synthesized via various artificial methods such as chemical synthesis and biotransformation, natural vanillin is still preferred by consumers as it is untampered by preservatives and eliminates food safety concerns. The essential oil derived from the beans is considered safe for inhalation and topical use when diluted in a carrier oil (Baqueiro & Guerrero, 2017).

*Vanilla*is thereby an economically significant orchid. With the increasing demand for vanilla vines, alternative ways to mass produce this plant species are reported. In recent years, the propagation using tissue culture techniques has shown advantages over conventional methods (Tan & Chin, 2015). Vanilla plants thrive in environments with average warm temperatures, bright indirect sunlight with high humidity. The climatic conditions of the United Arab Emirates (UAE) are subtropical, arid with hot summer during July and August where temperatures peak above 40°C. In order to achieve sustainability in food production, food and vegetable crops are being encouraged for their cultivation in UAE (Qaydi, 2016).In the present study, we report the cultivation and production of vanilla under greenhouse conditions.

Materials and Methods

Cultivation of *V. planifolia*

The cultivation site of *V. planifolia* located at the coordinate's 24°51′49.0″ N 55°21′40.2″ E, Dubai, UAE.Vanilla plant obtained from India was made into cuttings of 50 cm long for propagation. Plant petioles attached to leaves aid in determining the direction in which cutting should be planted. The plantation was initiated on 10 December 2015. 10 vanilla plants were grown organically under controlled greenhouse conditions. Agriculture grade sand and plant-based-soil-compost constituted the planting medium. The plants were first raised in pots to initiate roots and later transferred to the greenhouse (8 m × 16 m with 50-60% light intensity) with root ball added to the mixed substrate and separated by plastic edgers. A hygrometer was installed in the greenhouse to measure humidity and thermostat to monitor the temperature. Plants were grown in one line with 1 m gap between the plants. Vanilla plants received indirect sunlight for 6 h daily and irrigated with fresh water when the growing medium was dry to at least 2-4 inch from the surface to moisten the medium. Care was taken such that irrigation levels and did not reach saturation in order to mitigate root rot disease. Compost was added at a rate of 4 kg m^{-2} every three months for improving soil quality.

Soil and irrigation water

The plants were irrigated using freshwater provided by Dubai Electricity and Water Authority (DEWA) and water quality was analyzed as per standard agricultural applications. Agriculture grade soil recommended by the Dubai Municipality was used to prepare soil-compost substrate at a composition of soil:humus at 4:1 v/v to grow *V. planifolia*plants. A mixture consisting of red sand, the soil conditioner and compost at 3:1:1 w:w:v, 30 kg soil: 10 kg soil conditioner: 10 kg compost was utilized. Plants in small pots were placed in a greenhouse with indirect sunlight for 6 h per day to enable plant growth and proliferation. A stake was used as support for the creeper to climb and grow vertically. Vanilla plants were tied to the support using clips to secure the branches with the progression of growth.

Pollination and post-harvest processing

Vanilla flowers are hermaphroditic, fertile but incapable of self-pollination due to the closed structure of the flower. *V. planifolia* blooms only once for 6 weeks per annum and the flowers last for a day. At this stage the blossoms were hand-pollinated at around 11 am (Palama et al., 2011). Post-harvest processing was carried out after grading them based on the length of vanilla beans produced. The pods were washed with clean water and then submerged for 3-4 min. in hot water at 70°C for surface sterilization and blanching until the green pods started to change its color. The warm beans after hot water treatment were placed on a screen to remove excess water and kept in a dry blanket and wrapped tightly for further curing. The treated beans were then transferred immediately to a wooden box lined with blanket for sweating and continued for 36-48 hours at 48-50°C (Gabriel et al., 1999).

Drying vanilla beans and conditioning

The beans were spread for sun drying over a wooden loft on a clean black blanket from 12 noon-3 pm when temperatures were at their highest during the day. The temperature of the bean at this time was raised to 50°C and the bundles were transferred to the sweating box. Sun-drying and sweating were continued grade-wise. It was followed by a slow drying process which involved the spreading of the beans in racks present in a well-ventilated room maintained at an ambient temperature of 35°C and relative humidity of 70% (Palama et al., 2011). The dried and classified beans were tied in bundles of approximate 150-250 g each and kept for conditioning inside wooden boxes lined with wax paper for a period of two months.

Results and Discussion

Growth characteristics of Vanilla

Vanillais a thermophilic plant and grows well when the daytime average temperature is between 26.7°C to 29.4°C and during the night between 18-24°C with a daily amplitude of 6-8°C (Gabriel Fouché et al., 1999). *V. planifolia* can flourish under controlled irrigation, humidity and temperature. This tropical environment does not exist naturally in the UAE. Hence,the required conditions were maintained in a greenhouse covered with UV-stabilized fiberglass to simulate a tropical climate (Table 1). The vegetative cuttings were planted at two leaf nodes of the plant in the growth medium ata 1-inch depth. The plants were irrigated using freshwater provided by Dubai Electricity and Water Authority (DEWA) daily for 5 min at 8 am using a drip irrigation system. The cuttings started to develop new roots after around 30 days of planting. The fully grown vanilla plants reached 1.5 m and maintained at this height through vanilla production (Figure 1).

Fig. 1. Growth of *V. planifolia* under greenhouse conditions

Analysis of soil and irrigation water

The red soil classified as "Typic torripsamments mixed hyperthermic" where mixed is the mineralogy class is the dominant soil type found in UAE (Shahid et al., 2014) (Natural Resources Conservation Service Soils, 2015). Soil characteristics include a neutral pH and non-saline nature (Soil Survey Division Staff, 1993) and no sodicity was observed (Table 2). All soil parameters given in Table 2 were in the acceptable range for agriculture purposes and therefore no additional treatments were required to transform the soil into arable levels for plantations. To augment soil properties and support vanilla growth, the soil was mixed with the soil conditioner which provided essential minerals and supported growth and vanilla production.

The characteristics of irrigation water used for vanilla production were analyzed for electrical conductivity (EC), soluble anions, (CO_3^{2-}, HCO_3^- Cl^- and SO_4^{2-}), soluble cations (Na, K, Mg) and pH. Based on the water

Table 1. Climatic conditions for the growth of *V. planifolia*

No.	Characteristics	Applied
1	Greenhouse climatic control system	Fan and pad cooling system
2	Illumination	Sunlight, 50 – 60% light intensity (no artificial illumination), indirect sunlight exposure at least 10 h day^{-1}
3	Temperature	16°C (winter, min.) 32°C summer, max.)
4	Relative Humidity % (RH)	60-70%
5	Soil base* Soil-compost (v/v)	4:1
6	Irrigation water	Freshwater (water salinity 263 μScm^{-1})
7	Watering, drip irrigation	4 l day^{-1}
9	Irrigation frequency	Lightly to moisten the pot and not at saturation (surface to be dry to at least 2 -4 inch before watering)
10	Fertilizers	Not applied
11	Manure application (for every three months)	4 kg m^{-2}
12	Pesticides/herbicides/fungicides application in soil or for the plant growth	Not applied

**V. planifolia* growing medium

Table 2. Analysis of soil saturation extract

Soil parameters	Units	Values
pH		6.95
Soil salinity (ECe)	µS/cm	1080
Soluble cations		
Calcium (Ca^{2+})	mg/l	88.0
Magnesium (Mg^{2+})	mg/l	22.0
Potassium (K^{+})	mg/l	32.0
Soluble anions		
Sulphates (SO^{2-})	mg/l	78.0
Chlorides(Cl^{-})	mg/l	156.0
Macronutrients		
Totalnitrogen (N)	%	<0.1
Phosphorous (P)	mg/l	0.5
Potassium (K)	mg/l	32.0
Micronutrients		
Iron (Fe)	mg/l	0.01
Copper (Cu)	mg/l	0.04
Manganese (Mn)	mg/l	0.03
Zinc (Zn)	mg/l	0.02
Nickle (Ni)	mg/l	0.02
Others		
Lead (Pb)	mg/l	<0.01
Chromium (Cr)	mg/l	<0.01
Cadmium (Cd)	mg/l	<0.01
Cobalt (Co)	mg/l	<0.01
Silver (Ag)	mg/l	<0.01
Arsenic (As)	mg/l	<0.01
Selenium (Se)	mg/l	<0.01
Mercury (Hg)	mg/l	<0.01

quality analysis,salinity, EC 263 µS/cm);sodicity [SAR 1.3 (mmoles/l)0.5] and residual sodium carbonates (RSC), 0.63 meq/l were found (Table 3). The water used for irrigation can be classified as medium salinity (250-750 µS/cm) and low sodium water (SAR < 10 mmoles/l) 0.5(Zaman et al., 2018;Rhoades and Kandiah, 1992) and RSC is in safe limit (<1.2 meq/l) (Eaton, 1950; Bajwa et al., 1983). Medium salinity water can be used safely in coarse-textured soil such as sandy and loamy soil. However, if the soils are fine-textured for example, clay, a moderate amount of leaching may be required to control salinity build-up (Zaman et al., 2018). Plants with moderate salinity tolerance can be grown in most cases without particular practices for salinity control. Low sodium water can be used for irrigation, however, the sodium sensitive crops such as stone fruit trees and avocados may accumulate injurious concentrations of sodium (Hayward & Bernstein, 1958; Oster et al., 2007).

Pollination and vanilla pod harvesting

V. planifolia takes 2-7 years to grow and reach a height of 10-15 m prior to blooming (Gabriel et al., 1999). After 2 years of vegetative growth, the vanilla plants started flowering. To initiate blooming, the growing medium was watered and then made to partially dry on soil surface for 2-3 weeks. The flowers were formed during February and March. On average there were 8-10 flowers per bunch. Due to the floral structure of vanilla, natural self-pollination is difficult. Pollination was carried out manually as practiced in commercial cultivation of the vanilla after opening the flowers in the morning and completed before noon. Only selected viable flowers were pollinated as per bunch size. Big bunches had more flowers and pollination lead to maximum sized beans whereas the small bunches had fewer flowers pollinated. The day following pollination, flowers withered and turned dark brown. Pollination was verified when the wilted flowers did not fall and no change indicated re-pollination was required. After 2 months from the date of pollination, pods began to appear (Figure 2a, b) and took 6-9 months to reach full maturity (Wongsheree et al., 2013). Vanilla bean harvesting was carried out in mid-September to December. At this stage, beans changed its hue from a dark green shade to light green with a yellow tinge. Immature beans produced an inferior product and the beans started splitting if picked too late. The pods were plucked once the tip started turning yellow by lifting the bunch in the opposite direction and detaching the beans. A sharp cutter was employed to pluck the pods from plants in order to prevent any potential damage that could occur otherwise. Bunch or broom harvesting was avoided as each vanilla bean matured at different duration.

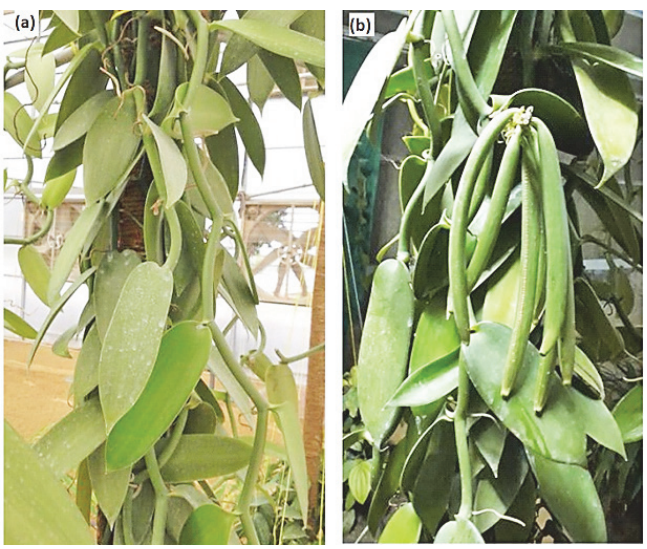

Fig. 2. (*a*) Vanilla vines climbed on galvanized pipes and (*b*) and vanilla beans

Table 3. Analysis of water used for irrigation

Soil parameters	Units	Values
pH		7.45
Water salinity (EC)	µS/cm	263
Total suspended solids (TSS)	mg/l	<5
Total dissolved solids (TDS)	mg/l	168.0
Total alkalinity to pH 4.5	mg/l	50.0
Soluble cations		
Sodium (Na^+)	mg/l	23.0
Calcium (Ca^{2+})	mg/l	19.0
Magnesium (Mg^{2+})	mg/l	3.0
Potassium (K^+)	mg/l	2.8
Sodium Adsorption Ratio-SAR	$mmolesl^{0.5}$	1.3
Soluble anions		
Sulphates	mg/l	<5.0
Chlorides (Cl^-)	mg/l	52.0
Carbonates, hardness	mg/l	50.0
Bicarbonates (HCO_3)	mg/l	61.0
Non carbonate hardness	mg/l	12.0
Total hardness $CaCO_3$	mg/l	62.0
Residual Sodium Carbonates, RSC	meq/l	0.63
Micronutrients		
Iron (Fe)	mg/l	<0.01
Copper (Cu)	mg/l	0.85
Manganese (Mn)	mg/l	0.21
Zinc (Zn)	mg/l	0.04
Others		
Lead (Pb)	mg/l	0.01
Chromium (Cr)	mg/l	0.49
Cobalt (Co)	mg/l	<0.01
Silver (Ag)	mg/l	<0.01
Arsenic (As)	mg/l	<0.01
Selenium (Se)	mg/l	<0.01
Mercury (Hg)	mg/l	<0.01

Processing, curing and productivity

The primary variable considered to determine harvest time is the maturity levels of the vanilla beans. Processing and curing of vanilla commenced within a week of harvest. As beans are odorless, processing and curing are necessary to develop its characteristic aroma. The pod size and appearance are the most important factors to consider as there is a direct relationship with aroma and vanillin content. The beans were classified according to length from grade 1-4 (Table 4) and segregated beans were transferred to a bamboo basket and surface sterilized and blanched in hot water at a temperature of 70°C for 2-5 min. The vanilla beans at this stage can be treated in an oven without heating with the light switched on for a period of 1-2 weeks until the fragrance intensifies (Baqueiro & Guerrero, 2017; Gabrielet al., 1999). Blanched beans were transferred immediately to a wooden box lined with blanket and kept for 36-48 hours in an environment maintained at 48-50°C for sweating. During the curing process, the beans attained a light brown color and started imparting aroma. In order to reduce the water content of the beans and curing, vanilla beans were sun-dried at noon and were then transferred to the sweating boxes. Sun-drying and sweating were continued grade-wise, the larger beans took more time for drying whereas the broken and splits dried faster (Table 4).

Table 4. Vanilla beans grading and drying

Grade	Bean length, cm	Sun drying process, days	Slow drying process, days
1	>15	10-15	20-40
2	10-15	5-10	10-30
3	10	5-10	10-15
4	splits	5-10	5-10

Further removal of the moisture content and development of flavor required the beans to fully ripen and undergo a slow drying process (Table 4). It involved spreading the beans in racks in a well-ventilated room maintained at 35°C with a relative humidity of 70%. On completion of slow drying, the vanilla beans developed heavy longitudinal wrinkles, leathery and lustrous appearance with a brownish-black tint. The moisture content at this stage was found to be 30-35% (Gabriel et al., 1999). Cured beans were tested by rolling them around the fingers and checking for an upright form upon release. The dried and classified beans were bundled, 150-250 g each, tied with a thread and kept for conditioning inside wooden boxes lined with wax paper for two months which resulted in further loss of three to four percent moisture with their fragrance reaching its full potential. Finally, the bundles were wrapped in wax papers and stored in airtight containers. Vanilla pods of 0.5-1 kg were placed in a vacuum and packaged in plastic pouches to prolong freshness. Each processed fruit averaged between 3 to 5 g based on size leading to an aggregate of 200-335 vanilla beans per kg of dry beans (Table 5). 20 kg of fresh vanilla bean pods were harvested from ten plants (Figure 3) and after three months of processing 4 kg of dry beans were obtained (Figure 4). In order to preserve quality and fragrance and to prevent molds, the processed vanilla was stored in a cool and dry place. The quality of vanilla beans is determined by the yield of the product,the total reduction in weight from fresh green pods to conditioned beans ranged

Table 5. Growth and yields of *V. planifolia*

No	Characteristics	Unit
1	Plant height	1.5 m
2	Spacing of plants (plant to plant)	3 m x 1 m
3	Flowering period	Starts by January – March
4	Average number of flowers/ bunch	8 -10
5	Pollination method Manual	Morning hours after opening till noon, preferably by 7.00 to 8.00 am
6	Vanilla bean fresh weight / 10 beans	202 g
7	Vanilla bean dry weight / 10 beans	38.6 g
8	Length of the pods (average 10 pods)	19 cm
9	Width of the pods (average 10 pods)	1 cm
10	Yield/ 10 plant	4.68 kg
11	Total yield of the beans fresh weight / 10 plants	20.5 kg
12	Total yield of the beans dry weight / 10 plants (after blanching and drying)	4.68 kg
13	Processed bean, dry weight/ bean	3.86 g
14	Number of processed beans, dry wtkg^{-1}	259
15	Approximate price per kg (AED)	4000 - 6000

Fig. 3. Freshly harvested pods, light brown color tip shows right time for picking pods for curing process

Fig. 4. The processed, cured and dried vanilla pods for packaging

from 4.5:1 to 6:1 depending on the grade of the vanilla beans.

Conclusions

Pilot-Scale production of *V. Planifolia* conducted shows the possibilities of scaling up under UAE conditions. The result of vanilla production involves parameters such as soil fertility, cultivation conditions, fertilization and the plant's variety. The present study has shown that an average 3 kg fresh weight of vanilla beans produced from each vanilla plant. Vanilla grown under fertilized and unfertilized conditions produced 100 g/ plant/year with an annual production of 1.5 kg of fruits per plant in the second year (Diez et al., 2016).From the experimental trials, it can be concluded that implementing the practices and procedures followed will help expand the *V. planifolia* plantation in the UAE. With the increasing demand and productivity, vanilla cultivation can be

adopted and novel methods for vanilla extraction can be considered. The production pattern of vanilla plants was not always the same from year to year. The cultivated and well-maintained vanilla plant can be productive for 3-4 years and the total yield decline until the seventh harvest (Wongsheree et al., 2013).

The average market price of one vanilla bean is 20-30 Arab Emirates Dirham ($ 6-8) as of 2019 which would mark the product at 4000 to 6000 AED per kg ($1100-1600). Currently, vanilla is fetching upwards of $600 per kg and over the past few years, the worldwide market for organic vanilla have shown an increasing trend for its demand and forecasted to reach USD 207 million by 2022 at a compound annual growth rate of 18.24% (Pilling, 2018) ("Organic Vanilla Market Size, Share, Demand, Competitors Strategy, Regional Analysis and Growth Forecast to 2022 - Reuters," 2019). The Minister of State for Food Security Her Excellency Mariam Hareb Almheiri in November 2018 during the UAE Government's second Annual Meeting presented the *National Strategy for Food Security*. One of the mission's objectives is to develop a comprehensive national system based on enabling sustainable food production through the use of modern technologies and enhancing local production. The introduction of *V. planifolia*in the UAE supports this vision and is a step forward to boosting the agriculture sector of the economy.

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