Jasminum grandiflorum: Influence of Flower Processing and Geographic Origin on Flower Absolute Composition

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Abstract

Five Jasminum grandiflorum flower absolutes harvested as flower buds and processed in the “J. sambac-way” in different locations in the southern Indian state of Tamil Nadu were analyzed using gas chromatography (GC) and GC-mass spectrometry. These absolutes were compared with 5 commercial Indian J. grandiflorum flower absolutes manufactured in the traditional “J. grandiflorum-way” from open flowers. Focus was placed on 42 key ingredients to investigate the influence of such a flower processing on the absolute composition. Our study established olfactive and composition differences of such absolutes produced via the “J. sambac-way.” In addition, geographic variations in this species were analyzed by comparing 5 commercial Indian J. grandiflorum flower absolutes with absolutes from Egypt and Morocco, respectively. A composition range of the absolutes was established for the 3 main J. grandiflorum flower grower countries using a total of 14 commercial samples. The 12 main ingredients in the absolutes showed variations between 4.3% and 89.7%.

Keywords

Jasminum grandiflorum, oleaceae, flower processing, geographic origin: India, Egypt and Morocco, flower absolute composition, odor

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The introduction of synthetic aroma molecules in the middle of the 19th century¹-³ has changed the perfumer’s palette from 100% natural ingredients before to approximately 5% naturals today. However, absolutes and essential oils still play a significant role in modern perfumery, especially in fine fragrances.⁴,⁵ While the key natural ingredients in perfumery have not changed much in the last decades,⁴ the natural palette is still expanding. Today, the addition of really new naturals is more the exception than the norm due to increased regulatory and registration requirements and they are mainly used for the creation of prestigious fine fragrances.⁶,⁷

Currently, supercritical carbon dioxide (CO₂) extracts experienced a revival as the technology is becoming more affordable.⁸ Only very few debutants have gained at least some volume like Pink Pepper essential oil and the respective CO₂ extracts from the berries of the 2 Schinus species molle L.⁹,¹⁰ and terebinthifolius Raddi,¹¹,¹² respectively. Another example is the absolute of Jasminum sambac (L.) Ait.,¹³ which still remains the little brother of J. officinale L. subsp. grandiflorum (L.) E. Laguna,¹⁴ commonly known as J. grandiflorum L.¹⁵-²⁰

It is worth to note that the flower processing of both jasmine species prior to concrete manufacturing is significantly different. The extraction processes leading to the concrete and consecutively to the respective absolute, however, are identical. These 2 different work streams for flower preparation have been established over the years due to different usage patterns of the 2 Jasminum species. This is mainly linked to the fact that the more robust and bigger flower buds of J. sambac are preferred in ornamental use over the much smaller and more delicate J. grandiflorum buds. The difference between the 2 species is very obvious from the kg/flower equivalent and also reflected in the price dependency of the flowers and subsequently the flower harvesting state. Only the remaining J. sambac buds, which are not sold on flower markets during the day for ornamental use, are purchased from raw material manufacturers, while J. grandiflorum flowers are picked from the farmers as fully blossomed out open flowers nearly exclusively for concrete production. Jasminum grandiflorum flowers are directly extracted (“J. grandiflorum-way”), while J. sambac buds awaiting their

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flourishing spread on a floor before they are extracted the same night ("J. sambac-way") as only fully blossomed out flowers are giving the maximum concrete yield. For a detailed comparison of the 2 Jasminum species: sambac and grandiflorum, see Table 1.

While the influence of CO₂ extraction on composition has been described in the literature, to the best of our knowledge, no study has been carried out to establish the influence of a “J. sambac-way” flower treatment on J. grandiflorum absolute composition. To eliminate normal geographical variability, samples from different locations were used. Here, we report analyses of 5 J. grandiflorum flower absolutes all originating from different locations in the southern Indian state Tamil Nadu. These absolutes were processed in the traditional “J. sambac-way”, starting from flower buds, which were then spread out on the floor to blossom prior to extraction. These were compared with 5 commercially available J. grandiflorum absolutes from India, all processed in the traditional “J. grandiflorum-way.” In addition, geographic variations were investigated in J. grandiflorum by comparing the composition of commercial Indian flower absolutes with absolutes from Egypt and Morocco, respectively, to establish a country-specific composition range.

**Results and Discussion**

All J. grandiflorum absolutes were analyzed by gas chromatography (GC) and GC/mass spectrometry (MS). Constituents were identified by comparing their mass spectra with known compounds, published spectra, or the Symrise in-house library. We focused our analyses on 42 constituents, covering major ingredients as well as compounds that help to distinguish between various Jasminum species including 2 epimeric methyl jasmonates. Thirty-eight of these molecules were identified in a previous publication and 4 components were additionally added as they are monitored by other companies. 26-28 2-Phenylethyl alcohol (retention index 1090), phenylacetaldehyde oxime (1250), 1(10),5-germacradien-4-ol (1561), (2E,6E)-farnesol (1698), (2E,6E)-farnesyl acetate (1817), and 2-phenylethyl salicylate (1915) were not detected in any J. grandiflorum absolute and therefore not reported in Tables 2 and 3. Ethyl linoleate (2137) was only present in 3 commercial samples, 1 Indian J (<0.1%), and 2 Egyptian absolutes P/Q (0.2/0.1%), all obtained from French suppliers. The remaining 35 compounds represented between 78.7% (T) and 93.5% (F) of the GC-detectable fraction and on average 86.6% for the 20 absolutes.

In India, J. grandiflorum shrubs (family: Oleaceae) can be found in varying degrees throughout peninsular India and the Indo-Gangetic plains. The state of Tamil Nadu, located geographically in the central part of the southern extremity of the Indian peninsula, however, has by far the largest acreage under commercial J. grandiflorum cultivation in India. Other Indian states with a significant jasmine crop area are Karnataka, Andhra Pradesh, West Bengal, Uttar Pradesh, and Rajasthan. In India, J. grandiflorum season normally lasts from June to November reaching its peak from the end of July to September (Table 1). Our first focus was placed on the comparison of 5 Indian J. grandiflorum flower absolutes A-E originating from the south Indian state Tamil Nadu with 5 commercial Indian absolutes F-J, which were produced from 4 different suppliers. Absolutes F and G were produced at the same time with flowers from the same region. While the commercial absolutes F-J were produced the standard way from open

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**Table 1. Indian Jasminum sambac and J. grandiflorum—Fact Sheet.**

| Flower                  | J. sambac | J. grandiflorum |
|-------------------------|-----------|----------------|
| Flowers equal to 1 kg   | 5000-6000 | 11 000-12 000  |
| Flowers (kg)/picker/day | 5-6       | 2-3            |
| Buds                    | Day break (6 am) | Day break (6 am); for buds (7 am) |
| Night (6-8 pm)          | Night (6-8 pm) | June-November  |
| March-September         | March-September | End July-September |
| April-June              | April-June | 95             |
| Ornamental use, price, and season | Variable depending on time of day and supply | Constant depending on supply |
| Price peak              | Early morning | None |
| Early morning           | None       | 300/600        |
| Flowers (% used for absolute | 5     | 5              |
| Buds picked in early morning and stored until buds open (7-8 pm; extraction during night | Open flowers picked in early morning or during day; extraction during day |
| Open flowers (kg)/picker/day | 850/1500 | 300/600        |
| Robust                  | China      | Egypt, Morocco |
| Delicate                |            |                |

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*aPersonal communication R. S. Palaniswamy (Jasmine C. E. Pvt. Ltd., India).
bGood picker.
flowers, absolutes A-E were derived from buds harvested in the months of September and October approximately 24 hours before the open, flower would have been normally harvested (for details see Table 4 and Experimental section). Buds were spread out on the floor to blossom in a similar fashion used traditionally for J. sambuc absolute production and extracted the same night. The number of single ingredients varied significantly in all 5 lab samples A-E (Table 2) produced via the “J. sambuc-way.”

Focusing only on major ingredients (>2.0%, marked bold in Tables 2 and 3), the 5 absolutes A-E showed significant variability for these 12 main compounds between 30% for (Z)-jasmone and 71% for linalool (see also Table 5). Absolute B contained significantly more benzyl benzoate compared with the other 4 A/C/F and higher amounts of indole similar to sample E. Sample D showed significantly higher amounts of linalool and benzyl acetate but lower amounts of isophytol, (E)-phytol, squalene, and 2,3-epoxy squalene compared with others A-C/E/F. It is worth to mention the higher level of (Z)-methyl (E)-jasmonate compared with (Z)-methyl jasmonate in absolute F as the equilibrium should favor the (Z)-methyl jasmonate as seen in all other samples. We could rule out copulation and reanalysis confirmed the finding.
According to our supplier, there may be small but no significant agroclimatic differences between these 5 locations in the Indian state Tamil Nadu. Flowers for sample A were collected from the primary region of cultivation and are from the western part of Tamil Nadu comprising the higher elevation areas of the plateau region of South India. Flowers for samples B and C were from the middle elevation plateau region in the northwestern part of Tamil Nadu while flowers for samples D and E are from the lower elevation plateau region of south-central Tamil Nadu (see Table 4 for details).

Findings for the commercial samples F-J were a bit different from the lab samples. Variations range between 16% for benzyl acetate and 89.7% for indole (Table 5). Only indole, (Z)-jasmone, and (E)-phytyl acetate variations were higher compared with the lab samples, while all others were lower. Absolute I showed higher amounts of benzyl alcohol and eugenol levels and lower amounts of indole, isophytol, squalene, and 2,3-epoxy squalene compared with F-H/J.

Interestingly, our perfumers pointed out that the odor profile of samples A-E produced via the “J. sambac-way” was more

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Table 3. Comparison of 35 Constituents (Area %) of Commercial J. grandiflorum Flower Absolutes from Egypt M-Q and Morocco R-T.

| No. | RI  | Compound                                      | M | N  | O  | P  | Q  | R  | S  | T  |
|-----|-----|----------------------------------------------|---|----|----|----|----|----|----|----|
| 1   | 986 | (3Z)-Hexenyl acetate                          | t | 0.2| <0.1| t  | <0.1| <0.1| <0.1| <0.1|
| 2   | 1011| Benzyl alcohol                                | 1.3| 1.2| 0.9| 1.4| 1.2| 1.3| 1.7| 1.2|
| 3   | 1048| p-Cresol                                      | 0.3| 0.4| 0.4| 0.4| 0.2| 0.3| 0.3| 0.2|
| 4   | 1073| Methyl benzoate                               | 0.1| 0.1| 0.1| <0.1| <0.1| 0.1| <0.1| <0.1|
| 5   | 1085| Linalool                                      | 2.9| 2.9| 2.3| 3.0| 2.7| 3.0| 3.4| 3.0|
| 6   | 1092| Benzyl cyanide                                | <0.1| 0.1| <0.1| <0.1| <0.1| <0.1| <0.1| <0.1|
| 7   | 1134| Benzyl acetate                                | 15.7| 15.6| 14.3| 14.2| 12.2| 18.2| 14.8| 14.3|
| 8   | 1173| Methyl salicylate                             | <0.1| <0.1| <0.1| <0.1| <0.1| <0.1| <0.1| <0.1|
| 9   | 1254| Indole                                        | 1.2| 2.1| 2.2| 1.6| 1.0| 1.9| 1.6| 1.2|
| 10  | 1310| Methyl anthranilate                           | t | <0.1| t  | t  | t  | t  | <0.1| t  |
| 11  | 1328| Eugenol                                       | 2.0| 1.8| 2.0| 1.6| 0.9| 2.0| 2.2| 1.9|
| 12  | 1368| (Z)-Jasmone (1)                               | 2.0| 2.0| 2.0| 1.8| 2.2| 2.9| 2.3| 2.4|
| 13  | 1443| δ-Jasmine lactone (2)                         | 0.5| 0.3| 0.6| 0.4| 0.4| 1.1| 0.8| 1.2|
| 14  | 1483| (3Z,6E)-a-Farnesene                           | 0.2| 0.2| 0.3| 0.2| 0.4| <0.1| <0.1| <0.1|
| 15  | 1496| (3E,6E)-a-Farnesene                           | 1.2| 1.5| 1.2| 1.2| 1.7| 2.2| 1.6| 2.0|
| 16  | 1544| (3Z)-Hexenyl benzoate                         | 1.0| 1.0| 1.0| 1.0| 1.5| 1.2| 1.5| 1.1|
| 17  | 1548| (E)-Neralodol                                 | 0.1| 0.6| 0.1| 0.1| 0.3| 0.2| 0.2| 0.2|
| 18  | 1605| (Z)-Methyl jasmonate                          | 0.9| 0.9| 1.0| 0.9| 1.1| 1.5| 1.3| 1.2|
| 19  | 1634| (Z)-Methyl epi-jasmonate (trans-3)            | 0.1| 0.1| 0.1| 0.1| 0.1| 0.1| 0.1| 0.1|
| 20  | 1718| Benzyl benzoate                               | 10.0| 9.0| 9.5| 8.8| 8.5| 9.8| 12.0| 9.7|
| 21  | 1817| Benzyl salicylate                             | <0.1| 0.1| 0.1| <0.1| <0.1| <0.1| <0.1| <0.1|
| 22  | 1907| Methyl palmitate                              | 1.4| 1.5| 1.4| 1.5| 1.5| 1.2| 1.5| 1.4|
| 23  | 1937| Isophytol                                     | 6.5| 5.7| 6.3| 6.3| 7.9| 6.0| 5.7| 5.0|
| 24  | 2014| Geranylinalool                                 | 3.1| 2.8| 3.0| 2.9| 3.6| 3.6| 4.0| 3.2|
| 25  | 2072| Methyl linolate                               | 0.2| 0.2| 0.2| 0.3| 0.2| 0.2| 0.3| 0.3|
| 26  | 2074| Methyl linolenate                             | 2.4| 2.3| 2.4| 2.3| 1.9| 2.5| 2.5| 2.7|
| 27  | 2078| Methyl oleate                                 | 0.8| 0.8| 0.8| 0.8| 0.8| 0.7| 0.8| 0.8|
| 28  | 2096| (E)-Phytol                                    | 9.4| 7.9| 10.6| 8.6| 9.0| 10.6| 6.9| 6.0|
| 29  | 2109| Methyl stearate                               | 0.4| 0.6| 0.4| 0.5| 0.7| 0.5| 0.6| 0.4|
| 30  | 2208| (E)-Phytol acetate                            | 6.2| 4.5| 6.0| 5.5| 7.3| 6.3| 7.2| 5.6|
| 31  | 2300| Tricosene                                     | t | 1.2| 0.9| 0.2| <0.1| <0.1| <0.1| <0.1|
| 32  | 2552| Benzyl palmitate                              | - | - | - | 0.2| 0.3| - | - | 0.2|
| 33  | 2688| Benzyl linolenate                             | - | - | - | 0.3| 0.2| - | - | 0.4|
| 34  | 2792| Squalene                                      | 4.6| 4.6| 4.9| 4.6| 4.6| 6.6| 6.9| 6.6|
| 35  | 2911| 2,3-Epoxy squalene b                         | 10.7| 11.8| 11.5| 10.2| 10.2| 7.0| 7.3| 6.4|

Abbreviations: RI, retention index; tr, trace (<0.01%).

*a* Measured on ZB-1 column

*b* Correct isomer not determined; ‘-’ indicates not detected.
Table 4. Provenance (City/District/Geographic Coordinates), Harvest Time, and Processed Quantity (kg) of J. grandiflorum Flowers A-E/K/I From Tamil Nadu, India.

| Entry | City          | District  | Coordinates N/E (°) | Harvest time | Quantity (kg) |
|-------|---------------|-----------|---------------------|--------------|---------------|
| A     | Karamadei    | Coimbatore| 11.25/76.96         | 09/2010      | 30.3          |
| B     | Salem        | Salem     | 11.66/78.15         | 09/2010      | 33.7          |
| C     | Thirupattur  | Vellore   | 12.51/78.57         | 10/2010      | 29.9          |
| D     | Nilakottai   | Dindigul  | 10.16/77.85         | 09/2010      | 31.7          |
| E     | Kodai Road   | Dindigul  | 10.18/77.91         | 10/2010      | 31.4          |
| K     | Ayarpadi     | Coimbatore| 11.25/76.96         | 11/2012      | 35.8          |
| L     | Ayarpadi     | Coimbatore| 11.25/76.96         | 11/2012      | 41.3          |

reminiscent of a living flower with a much fresher, green, and more natural floral note compared with the commercial absolutes F-J produced via the traditional “J. grandiflorum-way” from already opened flowers (for details see Table 6). The odor was very appealing for our perfumers, and the odor differences were also mirrored in the composition. We focused only on compounds where we saw a lower or higher trend over all 5 lab samples A-E compared with the commercial samples F-J. The lab samples generated via the “J. sambac-way” contained higher amounts of (Z)-jasmine (1) and δ-jasmine lactone (2) but lower amounts of (3Z,6E)-α-farnesene, geranylinalool, methyl oleate, methyl stearate, and 2,3-epoxy squalene. Especially (Z)-jasmine (1) and δ-jasmine lactone (2) (Figure 1) caught our attention as the odor descriptions fitted quite well to the odor differences.

The above comparison was based on pilot plant samples using small amounts of plant materials, whereas commercial samples using large quantities. Oftentimes, for commercial samples, various jasmine lots are pooled into 1 batch to achieve a commercial standardization to fulfill customers’ quality control standards. To prove our hypothesis further and to draw a more reliable conclusion, we decided to repeat a trial 2 years later using similar amounts of plant materials from the same growing region and process both under pilot plant conditions (Tables 2 and 4 entry K and L).

Absolute K was produced by the “J. sambac-way” while absolute L by the traditional “J. grandiflorum-way.” This also eliminated possible processing differences and ruled-out a one-off annual effect. The exceptionally high levels of p-cresol in both samples L and K and the high amount of (3E,6E)-α-farnesene in K are worth to mention as they were not detected in samples A-J. The trend for 5 compounds stayed the same, while (3Z,6E)-α-farnesene and methyl stearate were detected in equal amounts. Geranylinalool, methyl oleate, and 2,3-epoxy squalene in absolute K were higher, while the (Z)-jasmine (1) level was lower compared with trials A-E. δ-Jasmine lactone (2) showed the same results as before.

Both (Z)-jasmine (1) and δ-jasmine lactone (2) are derived via the lipoxgenase (LOX) pathway of plants starting from the fatty acids linoleic and α-linolenic acid.29–32 (Z)-Methyl jasmonate (trans-3),24 (Z)-methyl epojasmonate (cis-3),33 and (Z)-3-hexenol derivatives34 are also formed via the LOX pathway but are not found in higher amounts. A closer look into literature showed their biological importance.35-39 (Z)-Jasmonate (1) is released in some plants when the plant is damaged by herbivores and plays a role in plant defense and attracting pollinators.35,40 δ-Jasmine lactone (2) is also released in response to multiple stresses as demonstrated in tea leaves.27

Table 5. Variability (%) for 12 Main Ingredients (>2.0%) in J. grandiflorum Flower Absolutes From India A-E (“J. sambac-Way”), F-J (Commercial), Egypt M-Q, and Morocco R-T.

| Compound            | Variability (%) |
|---------------------|-----------------|
|                     | A-E  | F-J  | M-Q  | R-T  |
| Linalool            | 71.0 | 31.5 | 23.3 | 11.8 |
| Benzyl acetate      | 49.6 | 16.0 | 22.3 | 21.4 |
| Indole              | 50.0 | 89.7 | 54.5 | 36.8 |
| (Z)-Jasmine         | 29.8 | 50.0 | 18.2 | 20.7 |
| Benzyl benzoate     | 60.8 | 29.9 | 15.0 | 19.2 |
| Isophytol           | 42.7 | 32.1 | 27.8 | 16.7 |
| Geranylinalool      | 36.8 | 21.1 | 22.2 | 20.0 |
| Methyl linolenate   | 54.2 | 26.1 | 12.0 | 7.4  |
| (E)-Phytol          | 64.3 | 42.2 | 25.5 | 43.4 |
| (E)-Phyril acetate  | 35.6 | 42.6 | 38.4 | 22.2 |
| Squalene            | 63.0 | 44.9 | 6.1  | 4.3  |
| 2,3-Epoxysqualene   | 65.0 | 60.9 | 13.6 | 12.3 |

*Calculation of variability: (highest − lowest value)/highest value × 100 (%).
volatiles’ formation and the reason for emission or changes in composition are still in its infancy and deserve further attention.45–50

We also found other δ-lactone 2 related compounds (Figure 1). γ-Jasmine lactone (4) was undoubtedly identified in trace amounts in both samples K and L and in all other samples A J / M - T independent of locations.18,19,51 Lactone 4 can be either an artifact formed from δ-lactone 2 via ring opening and a consecutive acid-catalyzed dehydronhydration process51,52 or a natural product derived via the LOX pathway most likely from an α-ketol intermediate via ketol- endiol tautomerization.39 Compound 4 was characterized in various other natural products pointing more to the fact that a natural pathway to this molecule should exist.53 In the GC of K and L, we also found an additional major peak (0.7/0.5%) which was identified as the ethyl ester of the cleaved δ-jasmine lactone 5, which is definitively a production artifact. This peak was significantly higher in samples K and L compared with all other Indian samples whose levels range from trace to 0.1%. All Moroccan absolutes R - T contained 0.1% of ethyl 5-hydroxy-7-decanoate (5), while the Egyptian samples M - Q gave a mixed picture (0.2/0.7/t/0.4/0.1%).

Besides India, J. grandiflorum is grown only in 2 Northern African countries today on a larger commercial scale. The second largest producer of J. grandiflorum flowers after India is Egypt.5 Together, these 2 countries produce 95% of jasmine concrete.14,15 Most plantations are located in the Nile delta in the governorate of Gharbia in the municipal of Kotoor around the village of Shoubra Beloula and smaller quantities come from the governorate Faiyum in the municipal of Faiyum. The season lasts normally from June till October but is sometimes extended to November.15

Morocco is the third largest grower country of J. grandiflorum flowers but on a much smaller commercial scale compared with India and Egypt.5,15 Harvest season is early June to the middle of December. Plots are scattered in various areas like Maazis, Tiddas, M’Nasra, Khémisset, the surrounding of Rabat and other places exist as well.54

Significantly, smaller quantities of jasmine flowers are produced in France around Grasse.5 Even so, France has today other than in the past55 no real commercial relevance as a cultivation country of J. grandiflorum. The jasmine absolutes originating from France are used from very few precious fine fragrance houses. Nevertheless, till today French natural raw material manufacturers still play an important role as suppliers of various jasmine absolutes. They buy jasmine concretes from

| Origin     | Odor description                                                                                                                                                                                                                                                                                                                                 |
|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| India      | Premium very intense blooming jasmine quality with a floral, narcotic animalic indolic top note with sweet fruity banana-like aspects and a distinct green complex with a slightly salicylic and ylang-ylang-like note, body slightly fatty and a bit spicy. Dry-down: lasts up to 4 days on the smelling strip with a rich warm animalic jasmine note. |
| Egypt      | Compared with Indian quality less intense blooming, less narcotic indolic but more floral green aspects, a bit more oily and tea-like note. Dry-down: less long-lasting and radiant, up to 3 days on smelling strip.                                                                                                      |
| Morocco    | In comparison to the Indian quality, less intense blooming, less jasminic, narcotic indolic note and less fruity but with nice fresh green floral aspects and a more refined green note. Dry-down: least long-lasting jasmine (2 days on smelling strip) compared with samples from India and Egypt and less radiant. |
| India²     | Very similar to commercial Indian J. grandiflorum flower absolute but with a more natural fresh green, clean floral note reminiscent of fresh living flowers with some warm spicy aspects, a bit less animalic, fatty, and less banana-like fruity but more sweet natural fruity with slight apple aspects. |

²Produced via “J. sambac way”.

On smelling blotter as 10% ethanol solution.

Table 6. Odor Description of 3 Commercial J. grandiflorum Absolutes From India, Egypt, and Morocco and an Indian J. grandiflorum Absolute² Produced by the “J. sambac-Way”.b

| Origin     | Odor description                                                                                                                                                                                                                                                                                                                                 |
|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| India      | Premium very intense blooming jasmine quality with a floral, narcotic animalic indolic top note with sweet fruity banana-like aspects and a distinct green complex with a slightly salicylic and ylang-ylang-like note, body slightly fatty and a bit spicy. Dry-down: lasts up to 4 days on the smelling strip with a rich warm animalic jasmine note. |
| Egypt      | Compared with Indian quality less intense blooming, less narcotic indolic but more floral green aspects, a bit more oily and tea-like note. Dry-down: less long-lasting and radiant, up to 3 days on smelling strip.                                                                                                      |
| Morocco    | In comparison to the Indian quality, less intense blooming, less jasminic, narcotic indolic note and less fruity but with nice fresh green floral aspects and a more refined green note. Dry-down: least long-lasting jasmine (2 days on smelling strip) compared with samples from India and Egypt and less radiant. |
| India²     | Very similar to commercial Indian J. grandiflorum flower absolute but with a more natural fresh green, clean floral note reminiscent of fresh living flowers with some warm spicy aspects, a bit less animalic, fatty, and less banana-like fruity but more sweet natural fruity with slight apple aspects. |

²Produced via “J. sambac way”.

On smelling blotter as 10% ethanol solution.

Figure 1. Lipoxygenase pathway derivative compounds: (Z)-jasmine (1), δ-jasmine lactone (2), (Z)-methyl jasmonate (3), γ-jasmine lactone (4), and ethyl 5-hydroxy-7-decanoate (5) derived from 2.
the respective producer countries and convert concretes into absolutes in France using their processing knowledge.

Besides these 4 countries, there are several more countries around the world where *J. grandiflorum* bushes are grown and which may still produce very minute quantities of jasmine flowers. South Africa has cultivated or is still cultivating a few hectares of jasmine bushes in the area of Rustenburg,15,54, same applies for countries like Italy, Spain, Algeria,34,55 Turkey,30 and China57 but all are not or no longer of any commercial relevance as concrete manufacturers.53,55

To complete our work on *J. grandiflorum*, we further investigated geographic variations covering today’s main growing countries: India, Egypt, and Morocco, respectively. Various studies have been published before 1995 on geographic comparisons covering countries that have since then lost their importance54,58 or covering only 2 countries.26,59 Only Monique Rémy60 compared all 3 locations at her lecture in Digne les Bains in 1994. Since then, French manufacturers share the commercial field with local producers, harvesting procedures have been refined, extraction techniques improved, and solvents like benzene, etc., banned due to regulatory reasons.

On top of the 5 commercial Indian absolutes F, J, we analyzed 5 commercial Egyptian M, Q, and 3 Moroccan R, T jasmine absolutes (Table 3) all from different suppliers to better understand the differences between the three current main growing countries: India, Egypt, and Morocco. In the Egyptian absolutes N and O, higher tricosene levels were found compared with the other 3 M, P, Q, (E)-Nerolidol was highest in the Egyptian sample N compared with the other Egyptian samples M, O, Q. The absolutes from Morocco R, T were comparable among each other except a higher (E)-phytol level in sample R and a slightly higher level of benzyl alcohol and benzyl benzoate in sample S.

In all, *J. grandiflorum* absolutes from the 3 locations, benzyl acetate, benzyl benzoate, 2,3-epoxy squalene, phytol, isophytol, (E)-phytol acetate, and squalene were identified as the main ingredients. These findings were in line with previously published *J. grandiflorum* compositions of this species from India,25,26,60,62,63 Egypt,26,59,60,64 and Morocco.59,60 Variations range between 6.1% for squalene and 54.5% for indole in the absolutes from Egypt M, Q and between 4.3% for squalene and 43.4% for (E)-phytol in the Moroccan absolutes R, T, respectively (Table 5) compared with the Indian commercial absolutes F, J ranging from 16.0% in benzyl acetate and 89.7% in indole. The general variability was lower in the absolutes from North Africa compared with the Indian absolutes. Indole variations were very high across all three geographic locations and have been well documented in literature before.34,61,65

Variations of linalool and benzyl acetate both following a circadian cycle61 were much less obvious in our investigation in the commercial samples compared with variations in other compounds like (E)-phytol acetate. (E)-Phytol has the highest variability in the absolutes from Morocco R, T similar to the Indian samples F, J, while (Z)-jasmonol has a high variability only in the Indian commercial samples F, J.61

Odor of the absolutes was comparable among the 3 locations but there are also obvious differences (Table 6), and the Indian absolutes were the most preferred. A detailed odor evaluation of 4 jasmine absolutes by our perfumers in a 10% solution in ethanol (EtOH) on smelling strips is given in Table 6. We used randomly *J. grandiflorum* from India as a reference.

Besides odor, the 3 locations can be distinguished via composition. As the number of samples was way too low to perform a proper statistic as outliers would have a big influence, therefore, we compared the locations manually. We split our analysis between 22 major compounds (>0.2% in average value) and 13 minor compounds. In Table 7, the composition range of the 3 commercial *J. grandiflorum* absolutes from India, Egypt, and Morocco is summarized with possible natural outliers in brackets. Thirteen out of 22 major compounds showed a similar composition range, including all fatty acid methyl esters (methyl palmitate, methyl linolenate, methyl oleate, and methyl stearate), and also benzyl alcohol, benzyl acetate, indole, eugenol, (3Z)-hexenyl benzoate, geranylinalool, isophytol, (E)-phytol, and (E)-phytol acetate. The commercial jasmine absolutes from India showed higher levels of linalool and benzyl benzoate and slightly higher levels of p-cresol compared with their North African counterparts. The Egyptian absolutes had a slightly higher content of δ-jasmine lactone and (3E,6E)-α-farnesene compared to the Indian absolutes. The commercial absolutes from Morocco featured the most deviations: δ-jasmine lactone, (3E,6E)-α-farnesene, (Z)-methyl jasmonate, and squalene levels were higher, and (Z)-jasmonol was slightly higher, while 2,3-epoxy squalene levels were lower compared with the absolutes from Egypt and India. All 3 locations showed a very similar composition for the 12 minor compounds other than the slightly higher amount of (3Z,6E)-α-farnesene and tricosene in the jasmine absolute from Egypt. However, in 3 out of 5 samples, tricosene was found in low amounts similar to the absolutes from India and Morocco.

In addition, we created a literature range for an Indian,34,61,62,63 Egyptian,26,58,39,60,64,66 and Moroccan59,60 absolute from published data taking single analysis as well as ranges into consideration. We have some doubts on values given in the publication from Verghese and Sunny63 for Indian *J. grandiflorum* absolutes as some compounds like (Z)-jasmonol, masonic acetate, and methyl anthranilate are significantly higher and isophytol levels are much lower compared with other literature data for the same species and our own values. Literature data points for Egyptian absolutes are well aligned and cover several analyses while only 2 references39,60 were found for the absolutes from Morocco. In general, our analyses are well aligned with the literature references, but benzyl acetate, methyl benzoate, and δ-jasmine lactone ranges are higher in literature for all 3 countries compared with our findings. Linalool levels are higher in literature for the Egyptian and Moroccan absolutes compared with our findings. A detailed comparison is presented in Table 7.

In summary, composition variations in natural products are a given and necessary for the survival of the species.66 Geographic origin plays a significant role in such variations as
Table 7. Composition Range (Area %) of Major (1-22) and Minor (1'-13') Compounds of Commercial J. grandiflorum Absolutes From India, Egypt, and Morocco and Comparison with Literature Data.

| Entry | No. | RI Tab 2/3 | Compound | Indiaa | Egypt | Morocco | India literature26,60,62,63 | Egypt literature26,54,60,64 | Morocco literature59,60 |
|-------|-----|------------|----------|--------|--------|---------|----------------------------|--------------------------|------------------------|
| 1     | 2   | 1011       | Benzyl alcohol | 0.4-1.2 (2.8) | 0.9-1.4 | 1.2-1.7 | 1.1-1.8 | 0.2-0.9 | nr                  |
| 2     | 3   | 1048       | p-Cresol   | 0.4-0.8 (1.2) | 0.2-0.4 | 0.2-0.3 | 0.6-1.5 | 0.1   | nr                  |
| 3     | 5   | 1085       | Linalool   | 3.7-5.4 | 2.3-3.0 | 3.0-3.4 | 3.5-8.2 | 3.0-6.0 | 4.4-5.9          |
| 4     | 7   | 1134       | Benzyl acetate | 15.5-18.7 | 14.2-15.7 | 14.3-18.2 | 18.1-24.5 (29.7) | 14.4-26.7 | 18.3-19.2          |
| 5     | 9   | 1254       | Indole     | 0.3-2.9 | 1.2-2.2 | 1.2-1.9 | 0.7-3.2 | 1.0-3.5 (6.5) | 1.0-1.1          |
| 6     | 11  | 1328       | Eugenol    | 1.2-3.0 | 0.9-2.0 | 1.9-2.2 | 1.4-3.0 (4.0) | 1.1-2.5 (3.4) | 1.1-1.16          |
| 7     | 12  | 1368       | (Z)-Jasmone | 1.2-2.4 | 1.8-2.2 | 2.3-2.9 | 1.5-3.7 (9.5) | 1.9-3.5 | 1.1-2.3          |
| 8     | 13  | 1443       | 6-Jasmine lactone | 0.2-0.4 | 0.3-0.6 | 0.8-1.2 | 0.3-1.5 | 0.6-1.5 | 1.1-2.3          |
| 9     | 15  | 1496       | (3E,6E)-α-Farnesene | 0.8-1.2 | 1.2-1.7 | 1.6-2.2 | nr    | 2.1-4.4 | nr                |
| 10    | 16  | 1544       | (3Z)-Hexenyl benzoate | 0.7-1.0 | 1.0-1.5 | 1.1-1.2 | nr    | 1.1-2.0 | nr                |
| 11    | 18  | 1605       | (Z)-Methyl jasmonate | 0.2-0.8 (1.1) | 0.9-1.1 | 1.2-1.5 | 0.2-0.8 (7.2) | 0.5-1.2 | 1.3               |
| 12    | 20  | 1718       | Benzyl benzoate | 11.4-18.7 | 8.5-10.0 | 9.7-12.0 | 11.1-21.2 | 8.0-16.4 | 11.0-16.3          |
| 13    | 22  | 1907       | Methyl palmitate | 1.5-1.8 | 1.4-1.5 | 1.2-1.5 | nr    | nr     | nr                |
| 14    | 23  | 1937       | Isophytol  | 6.4-8.0 | 5.7-7.9 | 5.0-6.0 | (2.0) | 5.0-8.0 | 6.9-9.8          |
| 15    | 24  | 2014       | Geranyllinalool | 3.0-3.8 | 2.8-3.6 | 3.2-4.0 | 2.5-4.4 | 2.3-3.5 (8.4) | 3.8-9.5          |
| 16    | 26  | 2074       | Methyl linoleate | 1.7-2.3 | 1.9-2.4 | 2.5-2.7 | nr    | 3.3-4.2 | nr                |
| 17    | 27  | 2078       | Methyl oleate | 0.8-1.0 | 0.8    | 0.7-0.8 | nr    | nr     | nr                |
| 18    | 28  | 2096       | (B)-Phytol | 4.8-10.9 | 7.9-10.6 | 6.0-10.6 | 7.0-10.9 (13.3) | 7.0-12.0 | 7.5-9.9          |
| 19    | 29  | 2109       | Methyl stearate | 0.2-1.0 | 0.4-0.7 | 0.4-0.6 | nr    | nr     | nr                |
| 20    | 30  | 2208       | (B)-Phytol acetate | 3.9-6.8 | 4.5-7.3 | 5.6-7.2 | 2.5-5.5 | 3.5-10.1 | 7.0               |
| 21    | 34  | 2792       | Squalene   | 2.7-4.9 | 4.6-4.9 | 6.6-6.9 | 2.5-4.5 | 3.5-6.0 | 4.8               |
| 22    | 35  | 2911       | 2,3-Epoxy squalene | 4.3 | 7.2-11.7 | 10.2-11.8 | 6.4-7.3 | 7.0-11.0 | 8.0-12.0 | 6.7               |
| 1'    | 1   | 986        | (3Z)-Hexenyl acetate | t < 0.1 | t < 0.2 | <0.1 | nr    | nr     | nr                |
| 2'    | 4   | 1073       | Methyl benzoate | <0.1-0.2 | <0.1-0.1 | <0.1-0.1 | 0.3-1.0 | 0.3-0.6 | 0.5               |
| 3'    | 6   | 1092       | Benzyl cyanide | nd-0.1 | <0.1-0.1 | <0.1 | nr    | nr     | nr                |
| 4'    | 8   | 1173       | Methyl salicylate | <0.1-0.1 | <0.1 | <0.1 | nr    | nr     | nr                |
| 5'    | 10  | 1310       | Methyl anthranilate | nd < t | t < 0.1 | t < 0.1 | 0.4-0.8 | nr    | nr                |
| 6'    | 14  | 1483       | (3Z,6E)-α-Farnesene | t < 0.1 | 0.2-0.4 | <0.1 | nr    | nr     | nr                |
| 7'    | 17  | 1548       | (E)-Nerolidol | 0.1-0.2 | 0.14-0.3 (0.6) | 0.2 | nr    | nr     | nr                |
| 8'    | 19  | 1634       | (Z)-Methyl α-p-jasmonate | <0.1-0.4 | 0.1 | 0.1 | nr    | nr     | nr                |
| 9'    | 21  | 1817       | Benzyl salicylate | 0.1-0.2 | <0.1-0.1 | <0.1 | nr    | nr     | nr                |
| 10'   | 25  | 2072       | Methyl linolate | 0.2 | 0.2-0.3 | 0.2-0.3 | nr    | nr     | nr                |
| 11'   | 31  | 2300       | Tricosene    | nd-0.2 | t < 0.2 (1.2) | nd <0.1 | nr    | nr     | nr                |
| 12'   | 32  | 2552       | Benzyl palmitate | nd-0.1 | nd-0.3 | nd-0.2 | nr    | nr     | nr                |
| 13'   | 33  | 2688       | Benzyl linolenate | nd-0.3 | nd-0.3 | nd-0.4 | nr    | nr     | nr                |

Abbreviations: Abbreviations: nd, not detected; nr, not reported; RI, retention index; tr, trace (≤0.01%); ( ), values in parenthesis are outliers.

aInclusive J. grandiflorum values from literature.25
bMeasured on ZB-1 column.
demonstrated here for *J. grandiflorum* and in a previous publication for *J. sambac*.

Harvest time and year also play a part in such composition differences. All the above points are influenced by various abiotic and biotic factors like climate, soil, herbivores, parasites, etc.

In commercial products, manufacturing processes should not be neglected as a further key factor for variations. However, suppliers also use such processes to reduce variations and to achieve a standardization of natural products according to customers’ specifications. Variations can be observed, too, when plants are harvested at different stages of their development. Harvesting and processing of plant material for the flavor and fragrance industry are oftentimes based on heritage and traditional knowledge but most of the time has never been scientifically questioned or assessed. Agricultural practices have taken traditional knowledge but most of the time has never been scientifically questioned or assessed.

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**Experimental**

**General**

GC/MS: Agilent 6890 GC (ZB-1: 60m × 0.25 mm × 0.25µm film thickness, carrier gas He, 60 °C-280 °C at 4 °C/min) connected to Finnigan MAT SSQ 7000 quadrupole mass spectrometer, 70 eV (EI mode), mass range 25-450amu. GC: Hewlett Packard 6890 with FID and sniffing port (for column and temperature program, see GC/MS). All solvents and reagents are commercial products (Merck) and were used as received.

**Plant Material**

*Jasminum grandiflorum* flower buds for absolutes A-E/K/L were harvested by farmers in the south Indian state of Tamil Nadu (for location details see Table 4) between 6 am and 11 am, 24 hours before they are normally picked as open flowers. From the flower markets, buds were transported to the factory where they arrived between 7.30 pm and 9 pm. Buds were spread on the floor for 4-5 hours to blossom and then extracted in the pilot plant. Opened flowers were picked in the traditional way and extracted for absolute L.

**Concrete/Absolute Manufacturing**

Buds were allowed to blossom out before extraction while freshly picked flowers were directly extracted with *n*-hexane followed by filtration and solvent evaporation under reduced pressure to yield a waxy dark brown fragrant concrete. Concrete was dissolved in ethanol, chilled, and filtered. The filtrate was evaporated under reduced pressure to obtain a reddish-brown viscous liquid absolute with a delicate jasmine odor. The average absolute yield starting from fresh *J. grandiflorum* buds (“*J. sambac-way””) was 0.17%.

Flower absolutes of *J. grandiflorum* (A-E/K/L) were processed and obtained from JASMINE Concrete Exports Pvt. Ltd., Chennai (Tamil Nadu), India.

**Commercial Absolutes**

All commercial samples from India F-J, Egypt M-Q, and Morocco R-T were sourced from various suppliers on the open market in India, Egypt, and France covering jasmine crops of the years 2009-2014.

**Spectral Data of Jasmine Lactones and Derivatives**

- (Z)-7-Decen-5-olide (=6-[Z]-pent-2-enyl)oxan-2-one = δ-jasmine lactone (2). RI_{DB-1} 1443, RI_{DB-WAX} 2262. C_{10}H_{16}O_2 M = 168. GC /MS m/z (%): 39 (9), 41 (20), 42 (9), 43 (18), 55 (32), 67 (8), 68 (9), 71 (74), 79 (7), 81 (10), 99 (100), 108 (10), 121 (1), 122 (1), 139 (1), 150 (7), 168 (7).

- (Z)-7-Decen-4-olide (=5-[Z]-hex-3-enyl)oxolan-2-one = γ-jasmolactone = γ-jasmine lactone (3). RI_{DB-1} 1402, RI_{DB-WAX} 2162. C_{10}H_{16}O_2 M = 168. GC/MS m/z (%): 27 (10), 29 (26), 39 (8), 41 (23), 54 (6), 55 (14), 56 (6), 57 (5), 67 (14), 68 (100), 69 (10), 79 (8), 81 (7), 85 (26), 93 (5), 95 (6), 98 (3), 108 (7), 111 (6), 122 (1), 139 (1), 150 (1), 168 (1).

- Ethyl (Z)-5-hydroxy-7-decenate (5). RI_{DB-1} 1533, RI_{DB-WAX} 2265. C_{12}H_{22}O_2 M = 214. GC/MS m/z (%): 39 (9), 41 (16), 42 (8), 43 (16), 45 (7), 55 (28), 67 (7), 68 (8), 71 (59), 79 (7), 81 (9), 99 (100), 108 (10), 115 (2), 122 (2), 133 (1), 139 (1) 145 (11), 150 (6), 168 (4), 196 (1).

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References

1. Pickenhagen W. History of odor and odorants. In: Büttner A, ed. Handbook of Odor. 1st ed. Springer; 2017:1-10.

2. Ohloff G, Pickenhagen W, Kraft P, eds. Historical aspects – chemical discoveries and modern perfumery. In: Scent and Chemistry: The Molecular World of Odors. 1st ed. Wiley-VCH; 2011:5-21.

3. Pybus DH. The history of aroma chemistry and perfume. In: Sell C, ed. The Chemistry of Fragrances. 2nd ed. Royal Society of Chemistry; 2006:33-43.

4. Surburg H, Panten J, eds. Natural raw materials in the flavor and fragrance industry. In: Common Fragrance and Flavor Materials. 5th ed. Wiley-VCH; 2006:177-238.

5. Lawrence BM. A preliminary report on the world production of some selected essential oils and countries. Perfum Flavor. 2009;44(3):27-55.

6. Gilman F, Syrene R, Keyari C, Kropp R, Speight L, McLear C. Essential oils from leaves and fruits of Schinus molle L. and Schinus terebinthifolius Raddi from Southern Brazil. J Food Sci. 2010;75(6):C466-C472. doi: 10.1111/j.1750-3841.2010.01711.x

7. Lavoine Hanneguelle S, Périech C, Schnaebele N, Humbert M. Development of new natural extracts. Chem Biodivers. 2014;11(11):1798-1820. doi:10.1002/cbdv.201400026

8. Hellivan P-J. The expanding supercritical fluid CO2 extract universe. Perfum Flavorist. 2012;37(11):26-34.

9. Marongiu B, Porcedda APS, Casu R, Pierucci P. Chemical composition of the oil and supercritical CO2 extract of Schinus molle L. Flavour Fragr J. 2004;19(6):554-558. doi:10.1002/ffj.1350

10. Maffei M, Chialva F. Essential oils from Schinus molle L. berries and leaves. Flavour Fragr J. 1990;5(1):49-52. doi:10.1002/ffj.2730050109

11. Bendaudou H, Romdhane M, Souchard JP, Cazaux S, Bouajila J. Chemical composition and antioxidant and antitumor activities of Schinus molle L. and Schinus terebinthifolius Raddi berries essential oils. J Food Sci. 2010;75(6):C466-C472. doi:10.1111/j.1750-3841.2010.01711.x

12. Santos ACAdos, Rossato M, Agostini F, et al. Chemical composition of the essential oils from leaves and fruits of Schinus molle L. and Schinus terebinthifolius Raddi from Southern Brazil. Journal of Essential Oil Bearing Plants. 2009;12(1):16-25. doi:10.1080/0972060X.2009.10643686

13. Braun NA, Sim S. Jasminum sambac flower absolutes from India and China—geographic variations. Nat Prod Commun. 2012;7(5):645-650.

14. N.N. Jasmine: an overview of its essential oil and sources. Perfum Flavor. 2019;44(2):42-48.

15. IFEAT. Socio-Economic Reports no. 4 - Jasmine: Jasminum grandiflorum and Jasminum sambac. Accessed July 28, 2020. https://ifeat.org/project/socio-economic-committee/

16. Camps AB. Atypical jasmines in perfumery. Perfum Flavor. 2009;34(9):20-26.

17. Laguna E. Jasminum officinale L. subsp. grandiflorum (L.) comb. nova. Tid Neger. 2006;8(XII):9-12.
35. Wasternack C, Hause B. Jasmonates: biosynthesis, perception, signal transduction and action in plant stress response, growth and development. An update to the 2007 review in Annals of Botany. *Ann Bot.* 2013;111(6):1021-1058. doi:10.1093/abt/mct067

36. Wasternack C, Jasmonates: an update on biosynthesis, signal transduction and action in plant stress response, growth and development. *Ann Bot.* 2007;100(4):681-697. doi:10.1093/ab/sum079

37. Cheong J-J, Choi YD. Methyl jasmonate as a vital substance in plants. *Trends Genet.* 2003;19(7):409-413. doi:10.1016/S0168-9525(03)00138-0

38. Preston CA, Lauc G, Baldwin IT. Methyl jasmonate is blowing in the wind, but can it act as a plant–plant airborne signal? *Biosci Syst Ecol.* 2001;29(10):1007-1023. doi:10.1016/S0888-1978(01)00047-3

39. Beale MH, Ward JL. Jasmonates: key players in the plant defence. *Nat Prod Rep.* 1998;15(6):533-548. doi:10.1039/a815533y

40. Birkett MA, Campbell CA, Chamberlain K, et al. New roles for cis-jasmonate as an insect semiochemical and in plant defense. *Proc Natl Acad Sci USA.* 2000;97(16):9329-9334. doi:10.1073/pnas.160241697

41. Joulain D, Laurent R. The absolute from flowers of *Jasminum grandiflorum* Vahl from India. *Flavour Fragr J.* 1995;10(3):193-197. doi:10.1002/ffj.2730100312

42. Macgregor CJ, Scott-Brown AS. Nocturnal pollination: an overlooked ecosystem service vulnerable to environmental change. *Emerg Top Life Sci.* 2020;4(1):19-32. doi:10.1016/ETLS20190134

43. Dobson HEM. Relationship between floral fragrance composition and type of pollinator. In: Pichersky E, Dudareva N, eds. *Plant volatiles: production, action and type of pollinator.* 1st ed. Springer; 2016:1-326.

44. Raju AJS. Pollination ecology of Indian *Jasminum grandiflorum*. *Flavour Fragr J.* 1992;7(4):1893-1902. doi:10.100114/ffj.2730070606

45. Preston CA, Laue G, Baldwin IT. Methyl jasmonate is blowing in the wind, but can it act as a plant–plant airborne signal? *Biosci Syst Ecol.* 2001;29(10):1007-1023. doi:10.1016/S0888-1978(01)00047-3

46. Maffei ME, Gertsch J, Appendix G. Plant volatiles: production, action and type of pollinator. In: Pichersky E, Dudareva N, eds. *Plant volatiles: production, action and type of pollinator.* 1st ed. Springer; 2016:1-326.

47. Wasternack C. Jasmonates: an update on biosynthesis, signal transduction and action in plant stress response, growth and development. *Ann Bot.* 2007;100(4):681-697. doi:10.1093/ab/sum079

48. Pichersky E, Noel JP, Dudareva N. Biosynthesis of plant volatiles: nature’s diversity and ingenuity. *Science.* 2006;311(5762):808-811. doi:10.1126/science.1118510

49. Dudareva N, Pichersky E, Gershenzon J. Biochemistry of plant volatiles. *Plant Physiol.* 2004;135(4):1893-1902. doi:10.1104/pp.104.049981

50. Watanabe N, Watanabe S, Nakajima R, et al. Formation of flower fragrance compounds from their precursors by enzymatic action during flower opening. *Bioi Sci Biotechnol Biochem.* 1993;57(7):1101-1106. doi:10.1271/bbb.57.1101

51. Stoffelsma J, Sipma G, Brouwer H, Cohen AM. Closer to natural jasmine (2nd joint perfumery symposium eastbourne, 1973 – British soc. of Perfumers and SOC. of Cosmet. Chem. of great Britain). *J Soc Cosmet Chem.* 1973;24:1-5.

52. Takahashi K, Someya T, Muraki S, Yoshida T. A new keto-alcohol, (-)-menthactone, (+)-iso-menthactone and minor components in peppermint oil. *Agric Biol Chem.* 1980;44(7):1535-1543.

53. Werkhoff P, Brehmke R, Breitlander W, Schreiber K. Enantioselective GC analysis of chiral flavor and fragrance chemicals. *Contact He&R.* 1995;64(5):7-11.

54. Garnero J, Joulain D, Buil P. Differenzierung des origins geographiques des absolutes de fleur de jamas et quelques constituent ineclid des concretes et absolues de jamas. *Rivista Ital EPPOS.* 1980;62(1):8-18.

55. Anac O. Gas chromatographic analysis of absolutes and volatile oil isolated from Turkish and foreign jasmine concretes. *Flavour Fragr J.* 1986;1(3):115-119. doi:10.1002/ffj.2730010305

56. Elena J-C. A century of jasmine. *Contact He&R.* 1994;62(8):3-9.

57. Verzele M, Maes G, Vuye A, et al. Chromatographic investigation of jasmine absolutes. *J Chromatogr A.* 1981;205(2):367-386. doi:10.1016/S0021-9673(00)82664-3

58. Lawrence BM. Progress in essential oils - Jasmine extracts. *Perfum Flavor.* 1988;13(3):69-76.

59. Remy M, Bayle JC, Casabianca H, Graff JB, Faugier V. Comparison analytique de differentes productions de *Jasmin grandiflorum*. *Flavour Fragr J.* 1995;10(3):193-197. doi:10.1002/ffj.2730100312

60. Raju AJS. Pollination ecology of *Jasminum angustifolium* Vahl from India. *Flavour Fragr J.* 1995;10(3):193-197. doi:10.1002/ffj.2730100312

61. Jirovetz L, Buchbauer G, Schweiger T, et al. Chemical composition, olfactory evaluation and antimicrobial activities of *Jasminum grandiflorum*. *Contact He&R.* 1995;64(5):7-11.

62. Watanabe N, Watanabe S, Nakajima R, et al. Formation of flower fragrance compounds from their precursors by enzymatic action during flower opening. *Bioi Sci Biotechnol Biochem.* 1993;57(7):1101-1106. doi:10.1271/bbb.57.1101