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Fragrance Testing of Jasmine (*Jasminum Sambac* Ait.) Flowers Using Electronic Nose Technology

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ABSTRACT: *The Jasmine (Jasminum sambac Ait.) flowers are highly fragrant and used for extraction of concrete and absolutes using solvent extraction process. The concrete and absolute are used for preparation of perfumes, confectioneries, toiletries etc. At present the quality of the jasmine flower being validated by some destructive analytical methods and human olfactory system. The aim of the study was to develop a reliable tool to recognize the flower quality in a non-destructive and quickest possible manner. In order to estimate the quality of the jasmine flowers based on the fragrance emanation using electronic nose technology (E – nose), a study was undertaken at the Department of Floriculture and Landscaping, Tamil Nadu Agricultural University, Coimbatore in collaboration with Centre for Development and Advanced Computing (C-DAC), Kolkata during the year 2013-2015. A specially designed Electronic Nose equipped with a Metaloxide semiconductor Sensor (MoS) has been used in this study. The result showed that, the E - nose device generated Aroma Index (AI) score increases over the passage of time varies from 0.41 in immature bud (I stage) to 4.26 in matured bud (V stage) this is in accordance with the basic nature of flower ie. the rate of fragrance release is increasing towards the maturity of the flower.*

Also the study of quantum release of fragrance was evaluated at different flower opening stages (from bud to fully opened flower) using E nose device. Aroma Index was taken at different flower opening intervals. It showed that, minimum Aroma Index of 5.41 was recorded in unopened closed bud stage and increased Aroma Index of 41.26 was recorded in the fully opened flowers. It is also in line with the fundamental concepts of low fragrance release in matured bud and fragrance increases gradually towards opening of flower. The concrete obtained from specific time interval of 10am, 4pm and 8pm were injected into GC-MS instrument and constituents were identified. The major components identified are 9-Octadecenoic acid (Z)-, phenylmethyl ester (Benzyl oleate), Nonadecane and 2, 6-Octadien-1-ol, 3,7 dimethyl-(Z)- (cis-Geraniol). The post harvest physiological parameters such as the respiration rate and ethylene emission rate were also found increasing as the time progresses.

Keywords: *Jasmine, Electronic Nose, MOS, volatile emission*

INTRODUCTION

Jasmines are distributed in tropical and subtropical countries of the world. Jasmines are grown commercially in India, Thailand, China, Sri Lanka and the Philippines for its fresh flowers. The genus *Jasminum* contains more than 200 species and is mostly tropical in distribution (Abdul Khader and Kumar, 1995)[1]. Though there are a large number of species and varieties in jasmine, commercial cultivation is confined to only a very few, *viz*., *Jasminum sambac*, *Jasminum auriculatum* and *Jasminum grandiflorum*, which are largely cultivated and *J. multiflorum* (Syn: *J. pubescence*) which is cultivated to a small extent. The flowers are highly fragrant and used for religious offerings in temples and highly preferred by ladies for adorning their hair. They are also used for extraction of essential oil which is used in the preparation of perfumes and scented water. The extract of jasmine flower, called concrete is highly valuable for perfume, confectionaries, cosmetics and toiletry industries.

Due to the advancement of chemical and instrumental research in revealing the fragrance compounds in nature and also in synthesizing those components in laboratory has been achieved to some

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extent. The natural odour of the flowers were perfect and unchanged, cannot be completely extracted and analysed. There are various methods of analyzing these natural extract from flowers. Till date these fragrance estimation were only of subjective methods followed by panel of skilled persons only. The analysis had been done through instruments like chromatography, spectrography etc., which requires technically trained personnel to operate them.

There is a specific need for portable, low power and field deployable instrument that can objectively assess fragrance estimation and capable of sensing the volatile compounds of the given sample and reliably predicts scores with a high degree of accuracy, so that the technology can roll out from laboratory to the industry. Electronic Nose is a unique tool that is Neural Network based Soft Computing Techniques are used to tune near accurate correlation smell print of multi-sensor array. The software framework has been designed with adequate flexibility and openness, so that may train the system of scoring reliably predicts such smell print scores. Since there is a growing demand for the fresh flowers, there arises a need to develop a technique to identify the flower quality in non-destructive and quickest possible manner. This kind of technique would facilitate export of these flowers to both short and long distance overseas markets without much loss of the post harvest quality.

The Jasmine (Jasminum sambac Ait.) flowers are highly fragrant and used for extraction of concrete and absolutes using solvent extraction process. The concrete and absolute are used for preparation of perfumes, confectioneries, toiletries etc. At present the quality of the jasmine flower being validated by some destructive analytical methods and human olfactory system. The aim of the study was to develop a reliable tool to recognize the flower quality in a non-destructive and quickest possible manner. In order to estimate the quality of the jasmine flowers based on the fragrance emanation using electronic nose technology (E – nose), a study was undertaken at the Department of Floriculture and Landscaping, Tamil Nadu Agricultural University, Coimbatore in collaboration with Centre for Development and Advanced Computing (C-DAC), Kolkata during the year 2013-2015. A specially designed Electronic Nose equipped with a Metaloxide semiconductor Sensor (MoS) has been used in this study. The result showed that, the E - nose device generated Aroma Index (AI) score increases over the passage of time varies from 0.41 in immature bud (I stage) to 4.26 in matured bud (V stage) this is in accordance with the basic nature of flower ie. the rate of fragrance release is increasing towards the maturity of the flower.

Also the study of quantum release of fragrance was evaluated at different flower opening stages (from bud to fully opened flower) using E nose device. Aroma Index was taken at different flower opening intervals. It showed that, minimum Aroma Index of 5.41 was recorded in unopened closed bud stage and increased Aroma Index of 41.26 was recorded in the fully opened flowers. It is also in line with the fundamental concepts of low fragrance release in matured bud and fragrance increases gradually towards opening of flower. The concrete obtained from specific time interval of 10am, 4pm and 8pm were injected into GC-MS instrument and constituents were identified. The major components identified are 9-Octadecenoic acid (Z)-, phenylmethyl ester (Benzyl oleate), Nonadecane and 2, 6-Octadien-1-ol, 3,7 dimethyl-(Z)- (cis-Geraniol). The post harvest physiological parameters such as the respiration rate and ethylene emission rate were also found increasing as the time progresses.

DESCRIPTION OF ELECTRONIC NOSE

The Handheld Electronic Nose for gradation of Jasmine based on aroma characteristics is having the following features. The system is small handheld device, touch-Screen based user interface, integrated odour delivery unit, both battery/AC Adapter operated, data storage in SD Memory Card in FAT32 file system, results in Graphics Display, sensor array consisting of five (5) MOS sensors and the report can also viewed through PC based report generation tool.

Electronic Nose system for gradation of Jasmine based on aroma characteristics comprises of two main components – (i) The Sniffing Unit and (ii) Data Processing Unit. The sniffing unit consists of the sensory and sensing unit. The sniffing unit is the odor capture and delivery system to the sensor array and the data processing unit is responsible for data acquisition from the sensor array through a proper signal conditioning circuit and the acquired data is processed to generate and display the Fragrance Index.

The experimental sniffing cycle consists of automated sequence of internal operations: (i) headspace generation, (ii) sampling, (iii) purging before the start of the next sniffing cycle. Initially these MOS sensors require heating for at least one hour to be stable. Heating is done by supplying 5 Volts to the heater coils of the sensors. This heating phase of sensors is referred to as Pre-heating.

The MOS sensors react to volatile compounds on contact; the adsorption of volatile compounds on the sensor surface causes a physical change of the sensor. The generation of aroma volatiles from the sample is called Headspace. Fixed air pressure is generated in the air-tight sample chamber to generate aroma volatiles. Sampling is the process in which the aroma volatiles generated during headspace are exposed to the sensor array in a controlled manner so as to maintain a constant operating condition all the time. A valve is made open and kept open for a fixed time so that aroma volatiles generated inside the sample holder may move to the sensor chamber at a fixed flow rate over a fixed period. During this entire period, changes on the electrical properties of all the sensors are recorded for analysis.

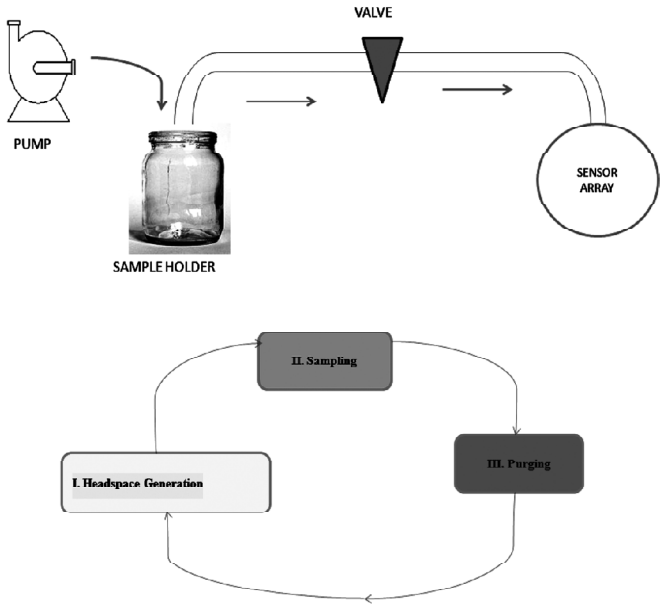

Figure 1: Sensor response during a complete sniffing cycle

During sampling period, aroma volatiles are adsorbed on the sensor surface. After every experimentation (i.e., sampling period), the sensor heads need to be cleared by exposing them to fresh air so that the adsorbed compounds get removed from the surface. This process of removing the adsorbed volatile compounds from sensor heads is called Purging, which brings the sensors to their base values to make the E-Nose ready for next experimentation.

The application is broken up into the following major categories: (i) Training (ii) Testing –Online Opening Index evaluation of flowers based on training database (iii) Reports on archived test results and (iv) Online Opening Index evaluation of Jasmine flower. The display size being small and in absence of keyboard, provision of data-entry by user is kept minimum and a virtual on-screen keyboard is designed for this purpose. A simple Flat File System (FAT32 format) on the SD card memory is used for data storage and retrieval.

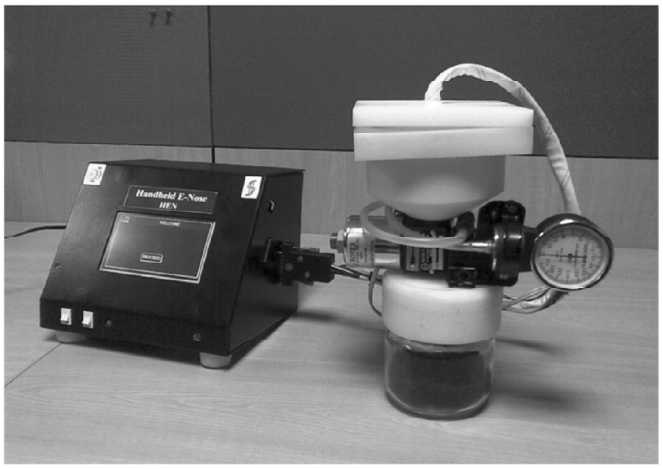

Figure 2: System Diagram of Handheld Electronic Nose

SELECTION OF SENSORS AND SENSOR ASSEMBLY MODULE

The experiment was undertaken by Centre for Development and Advanced Computing (C-DAC), Kolkata in coloration with Department of Floriculture and Landscaping, Tamil Nadu Agricultural University, Coimbatore during the year 2013-2014. The experimental material consisted of flowers of major species of Jasmine *i.e., Jasminum sambac* was used. Fresh flowers, *Jasminum sambac* which were collected from randomly selected plants and flowers (unopened fully matured flowers) were harvested in the early morning hours of around 5 am to 6 am during the entire period of study.

Samples, made from jasmine flowers *(Jasminum sambac)* of volume 15gm were tested under handheld e-Nose system, which produce a fragrance index of tested samples. Five Gas sensors have been identified and selected for the Electronic portable instrument after selectivity and sensitivity analysis of these sensors when exposed to aroma determining chemical compounds of Jasmine. In view of the processing power, memory and power constraints of the handheld instrument, we have chosen the best five (5) out of a few gas sensors in this phase. The three sensors operate at 10 volts and the rest two sensors operate at 5 volts. From the response of individual sensors to the Jasmine flowers, it is observed that the responses of the sensors –TGS 2600, TGS 826, TGS 2444, TGS 816, TGS 2610, TGS 2611and TGS 830 are

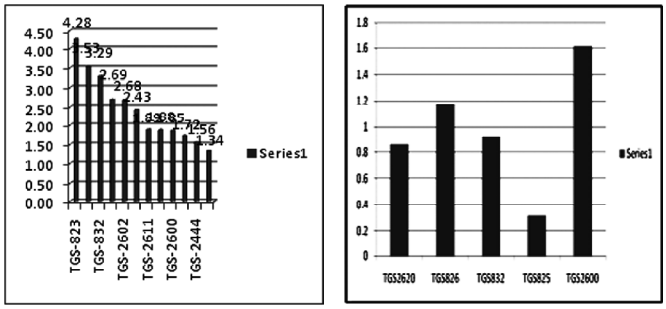

Figure 3: Selection of five MOS sensors specific to jasmine

not significant and hence have not been considered for inclusion in the sensor array in our experimental electronic nose for jasmine's classification. Each sensor is tuned for odor of a family of volatile compounds. Odor stimulus imprints a characteristic electronic pattern as fingerprint (or smell print) on sensor array. This smell print is statistically classified and resolved with suitable pattern recognition engine as a measurement of odor of the sample. Overall aroma of Jasmine is a complex mixture of Volatile Flavoury Compounds (VFC).

After finalizing the Sensor Array, we exposed different species of Jasmine flowers to this array and found that this array was able to classify different species of Jasmine flower. The Principal Component Analysis (PCA) was done based on the response matrix consists of five individual sensor responses during its sampling time of the sniffing operation. Individual sensor response is considered to be the difference or the distance calculated from its base value to its ultimate stable value. The PCA plot of Figure 2 shows the classification ability of the sensor array.

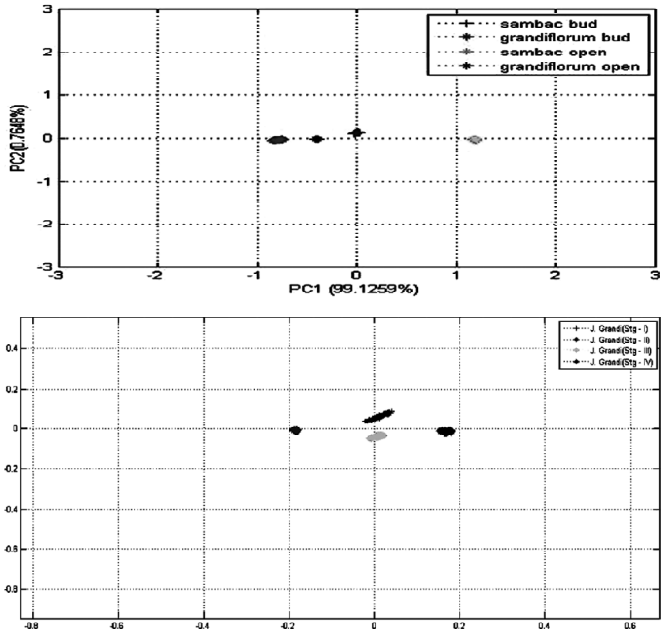

Figure 4: PCA plot for five different varieties of Jasmine flowers at different stages

The sensor array consisting of sensors for the aroma characterization for fresh flower fragrance detection are - TGS 823, TGS 825, TGS 832, TGS 2620 and TGS 2602.

EXPERIMENTAL PLAN

The fragrance emission pattern of jasmine flowers (*Jasminum sambac*) at various flower developmental stages were tested using electronic nose instrument. The entire flower developmental period (Approximately 14-15 days) was divided in to five stages (I – V). The different stages of harvesting were given under Table 1. The flowers were harvested and observations of Electronic Nose generated Aroma Index (AI), Ethylene Emission Rate and Respiration Rate were recorded at all the five developmental stages.

Table 1
Different harvesting stages of *Jasminum sambac* flowers

Name of the species	*Stage of harvest*	*Age of flower bud (days)*
Jasminum sambac	Stage I	5
	Stage II	8
	Stage III	10
	Stage IV	12
	Stage V	15

Jasmine flowers are commonly harvested at fully matured bud stage in the early morning hours. The harvested flowers are stated to open after harvest and opened fully in the evening. This is the physiological flower opening pattern in jasmine flowers. In another experiment jasmine flowers were harvested at physiologically fully matured bud stage in the early morning and the fragrance emission was monitored at different flower opening stages. The various flower opening indices (FOI) at different time intervals were categorized and given in the Table 2. The observations of Electronic Nose generated Aroma Index (AI),

Table 2
Flower Opening Index (FOI) chart of jasmine flowers (*Jasminum sambac*) of different flower opening stages

S.No	*Flower Opening Index*	*Flower opening pattern*
1	0	Un-Open Bud
2	0.5	Nearly Slight Open
3	1.0	Slightly Open
4	1.5	Nearly Half Open
5	2.0	Half Open
6	2.5	Nearly Full Open
7	3.0	Fully Open

Ethylene Emission Rate and Respiration Rate were recorded at different Flower Opening Index (FOI) of jasmine flowers.

Soxhlet Extraction

The compounds responsible for fragrance emission in fully opened Jasmine flowers were detected through the concrete extracted using Soxhlet extractor. The fresh samples of about 20 gram are taken in the extraction chamber placed in a tube above the extraction solvent. The solvent used was food grade Hexane (Analytical Reagent) to wash the sample using a reflux apparatus. When heated, the solvent evaporates into a gas, and then cools into a liquid in a condenser. It then refluxes back into the sample tube. This continuous cyclic process takes around 45 to 60 minutes per cycle until the concrete is separated from the sample. The solvent is evaporated off, by keeping it in the water bath and the amount of concrete is determined.

Gas chromatography

Later the extracted concrete samples at different interval of time were subjected to GC-MS analysis. About one micro litre of sample concentrate was injected into a Thermo GC - Trace Ultra Ver: 5.0,Thermo MS DSQ II gas chromatograph equipped with a flame ionization detector. The column used is DB 35 - MS Capillary Standard Non - Polar Column. The specifications of Gas Chromatography used for analysis; Column: 50m X 0.25mm internal diameter (i.d.) coated with PEG20M, film thickness: 0.15 pm, Carrier gas: N, with a flow rate at 1.2 ml/min, oven temperature: 60°C (4 min) + 220°C, injection and detector temperature: 200°C Split ratio: 10: 1

RESULTS AND DISCUSSION

The 2D plot is drawn based on dataset of four different samples of same species [*J. sambac*] of Jasmine flowers at same blossoming stage. It is observed that both plots are forming single cluster. The selected sensors' responses for Jasmine quality assessment are highly reliable since plot in 2D generate single cluster.

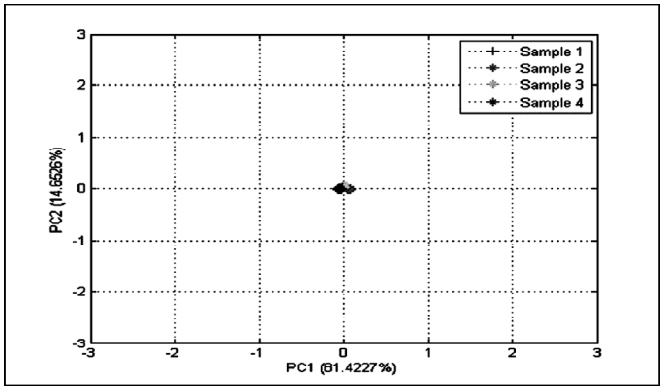

Figure 5: PCA Plot (2D)

Six response matrices, which were generated during the sampling of Jasmine flowers collected from five different gardens and made one sample from each garden and marked as sample 1 to sample 6, were analysed for PCA.

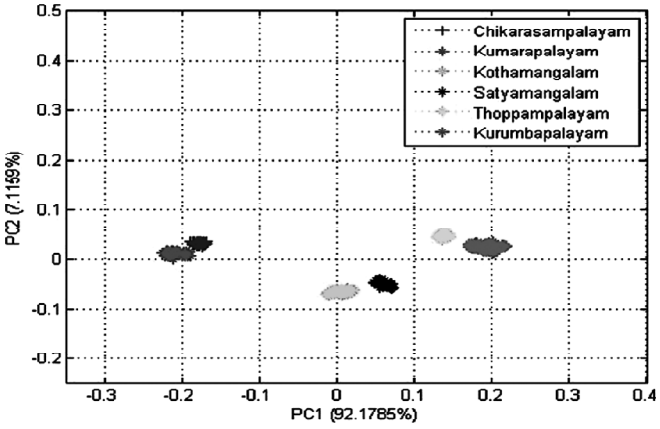

Figure 6: PCA Plot of jasmines collected from five different gardens

Three response matrices, which were generated during sampling of Jasmine samples collected from local vendors, Coimbatore, had been analyzed for PCA. As a result of extensive research, Tamil Nadu Agricultural University, Coimbatore has identified bio-chemical compounds that are available in Jasmine flower and are responsible for aroma as given in Table 3.

Table 3
Bio-chemical compounds present in Jasmine flower responsible for Aroma

Sl. No.	*Compounds*
1.	Benzyl alcohol
2.	Cycloheptasiloxane tetradecamethyl-
3.	Methyl benzoate
4.	Linalool
5.	Benzyl acetate
6.	Indole
7.	Cyclohexasiloxanedodecamethyl-
8.	Hexadecamethylcyclooctasiloxane
9	(-)-(R)-Jasmine Lactone
10	(E,E) α-Farnsene
11	(Z)-3-Hexenyl benzoate
12	N-Acetyl Methyl anthranilate
13	Cyclohexasiloxane
14	(E)-Methyl jasmonete
15	Benzyl benzoate
16	Isophytol

The parameters on fragrance estimation at various developmental stages of flowers and flower different flower opening stages were given respectively in the Table IV and Table V. Time taken for flower opening is an important character, which signifies the earliness or late flowering habit of the genotype. Both the habits are helpful in determining the availability of flowers for longer period (Abdul Khader and Kumar, 1995)[1].

E nose Aroma Index (AI)

The Electronic Nose generated Aroma Index (AI) of Jasmine flowers during different flower developmental stages were observed and the Aroma Index values were 0.41 in I stage, 0.83 in II stage, 1.58 in III stage, 2.53 in IV stage and 4.26 in V stage. It clearly indicates that the Metal oxide Sensor (MOS) used in the E- nose instrument, sniffed the compounds responsible for fragrance and generates the Aroma Index (AI) as the stage of maturity progresses. In case of fully matured harvested jasmine flowers were continuously observed from its fully matured closed unopened stage to fully opened condition. Based on our observation the e nose generated Aroma Index (AI), gradually increases from 5.41 in 10.00 am (Un-opened closed bud stage), 16.83 in 4.00 pm (Nearly slight open stage), 24.58 in 6.00pm (slightly opened stage), 32.53 in 6.00 pm (Half opened) and 41.26 in 8.00 pm (fully opened). As the flower opens, the fragrance emission is higher and the senescence of flower takes also place.

Respiration rate

Respiration rate of *Jasminum sambac* flowers was monitored at different flower developmental stages. It was noticed that, Co2 emission was not noticed in the stage I and stage II flower developmental stages. The Co2 emission rate was started increasing gradually from stage III onwards and the rate of emission at different developmental stages *viz*. stage (1.2ppm, stage IV (2.3ppm) and stage V (8.4 ppm). (Tanle IV). In the fully matured unopened harvested flowers, the respiration rate increased gradually at different time intervals. The respiration rate were as follows, in 8.4 ppm at 10.0 am, followed by 27.8 ppm at 4 pm which gradually increases steadily and reaches upto 56.8 ppm at 8 pm (Table 5) in the harvested flowers.

This is due to short supply of readily respirable substrates in the flowers due to onset of senescence. Similar results were reported by Coorts (1973) [12] in cut flowers and Maxie *et al*. (1973) [23] in carnation. Increased respiration leads to formation of free radicals with high oxidation potential. Free radicals promote senescence in tissues which in turn increases sensitivity to ethylene (Fig.2). Respiration is the central process in living cells that mediates the release of energy through the oxidative breakdown of carbon compounds (starch, sugar and organic acids) and the formation of carbon skeletons necessary for maintenance and synthetic reactions after harvest (Wills *et al*., 1998) [38]. In the present study, a respiratory climacteric rise from the initial level and a decline thereafter was noticed with all the treatments.

With regard to *J. sambac* under ambient conditions a similar trend was noticed, recording minimum rate of respiration rate and sufficient amount of carbohydrate levels. These significant levels of carbohydrates might have served as the substrate for respiration for a longer duration.

Evidences supporting this fact have been reported in case of flowers supplied with exogenous sugar, wherein maintained the pool of dry matter and respirable substrates were maintained at favourable levels thus promoting respiration (Coorts, 1973) [12] and in turn extending the longevity (Rogers, 1973) [31]. The observation of Maxie *et al.* (1973) [23] that the respiratory activity in flowers and the production of carbon-di-oxide by flowers was similar to the pattern in climacteric fruits, characterized by a rise in level of respiration with senescence also supports the present study.

Kaltaler and Steponkus (1976) [19] have associated the decline in respiratory activity of aging rose petals with their inability to metabolise substrates consequent to decline in activity of mitochondria in the aging petals. Moreover, increased respiratory activity leads to the formation of free radicals with high oxidation potential and these free radicals have been found to promote senescence in the tissues, associated with an increased sensitivity to ethylene (Baker *et al*., 1977[4]; Mishra *et al*., 1976) [25]. The typical climacteric respiratory rise reported in carnation cv. White Sim (Burger *et al*.1986) [6] and day-lily (Lukaszewski and Reid, 1989) [21] is consistent with the present result. In contrary, Trippi and Paulin (1984) [35] had reported a decrease in respiratory activity in carnation cv. White Sim.

Ethylene Synthesis

It was observed that there was no ethylene evolution observed till III flower developmental stage, while it was triggered during IV stage up to 1 ppm. Ethylene was started releasing rapidly after IV of harvest stage and it was 3.2 ppm. (Table 4). Ethylene evaluation was

also monitored in harvested fully unopended flower buds at different flower opening stages of jasmine flowers. *J. sambac* recorded an ethylene evolution rate with the range of 2.0 ppm and 22.8 ppm after harvest of fresh flowers at different time intervals. (Table 5). The results indicated that the rate of ethylene evolution increased rapidly after harvest upto 16 hours, after which the senescence of flower starts (Fig. 2). Similar results were observed by Mayak and and Halevy (1974) [24], Suttle and Kende (1978[32], 1980[33]) and Borochov *et al*., (1997) [7]. Also it was observed that as the flowers started showing symptoms of wilting, there was a rise in level of ethylene emission rate.

Table 4
e-nose generated Aroma Index (AI) of *Jasminum sambac* at different flower developmental stages

Species	*Harvesting Stages*	*E-nose Value (Aroma Index)*	*CO_2 Rate (ppm)*	*Ethylene Emission Rate (ppm)*
Jasminum sambac	**Stage I**	0.41	0	0
	Stage II	0.83	0	0
	Stage III	1.58	1.2	0
	Stage IV	2.53	2.3	1
	Stage V	4.26	8.4	3.2
SEm ±		0.018	0.007	0.002
CD at 5%		0.075	0.025	0.006

Table 5
e-nose generated Aroma Index (AI) of *Jasminum sambac* at different flower opening stages

Species	*Time*	**Flower Opening Index (FOP)*	*E-nose Value (Aroma Index)*	*CO_2 Rate (ppm)*	*Ethylene Emission Rate (ppm)*
Jasminum sambac	10.00 am	0	5.41	8.4	2.0
	04.00 pm	0.5	16.83	27.8	9.5
	06.00 pm	1	24.58	36.3	14.9
	07.00 pm	2	32.53	42.6	18.6
	08.00 pm	3	41.26	56.8	22.8
SEm ±			0.015	0.122	0.145
CD at 5%			0.210	0.265	0.351

Ethylene hormone has been known to play a crucial role in senescence of flowers, the sensitivity of which varies depending on the flower species (Redman *et al*., 2002) [30]. Ethylene reduces the longevity of some flowers causing rapid wilting of petals (e.g , carnations), shedding or shattering of petals, or other changes to petal tissues, such as loss or change of colour.

Earlier reports (Naidu and Reid, 1989) [27] have indicated that the flowers are ethylene sensitive based on the fact that though the flowers produce moderate ethylene during opening and senescence, they do not respond to exogenously applied ethylene (Veen, 1983) [37] indicating that this hormone is not involved in their senescence. Since no reports were available on *Jasminum* spp. with respect to ethylene evolution, however some records on wilting of flowers other than Jasmine caused by ethylene had been discussed. Involvement of ethylene in wilting of flowers (Borochov *et al.*, 1997) [7] has been observed in carnation (Ten Have and Woltering, 1997) [34] and in *Gypsophila paniculata* (Vandoorn and Reid, 1992) [36]. The visible responses of flowers to ethylene, including wilting, were found to be indicating the loss of turgor (Hanson and Kende, 1975) [15]. It has also been noticed that the flower parts including petals, sepals, the ovary and labellum were the major site of ethylene production (Chao Chia *et al*., 1991) [10] and that ethylene promoted the accumulation of sugars and inorganic materials in the ovary, with a simultaneous loss of fresh and dry weight of the petals. These are some evidences of ethylene sensitive species where in, ethylene in the major cause of wilting of flowers.

GC-MS Analysis

The concrete obtained from soxhlet extractor was injected into GC-MS instrument and constituents were identified by comparison of both mass spectra and retention indices, strictly measured on the same instrument with those of authentic jasmine samples. The identified constituents are listed in Tables 6 and Table 7 with their respective chromatogram obtained is shown on Fig. 11 and Fig. 12 exhibited significant compounds identified at specific time intervals (10.00 am, 4.00 pm and 8.00 pm). The GC-MS chromatogram at 10 AM shows that, the preliminary indication about the composition of some major volatile components. However, here its quantitative composition of these compounds differs considerably from the other samples. The jasmine flower possesses maximum composition and recorded peak during this time. They are Eicosanoic acid, phenylmethyl ester (Benzyl icosanoate) (26.47%), 9-Octadecenoic acid (Z)-, phenylmethyl ester (Benzyl oleate) (24.04%), Nonadecane (17.41%) and 2,6-Octadien-1-ol, 3,7 dimethyl-(Z)- (cis-Geraniol) (14.24%).

The GC-MS chromatogram of 4 PM shows that, the preliminary indication about the composition of some major volatile components as the flower starts to open. However, here its quantitative composition

of these compounds differs considerably from the other samples. The jasmine flower possesses major composition during this time. They are Hentriacontane (15.99%), Tetratriacontane (11.71%), and 9-Tricosene, (Z)- (10.62%).

The major active plant principles in the jasmine samples taken at 10 pm are reported to be identified about twenty eight constituents. They are, 9-Octadecenoic acid (Z)-, phenylmethyl ester (Benzyl oleate) (21.01%), 1-Octadecyne (15.35%) and Octadecanoic acid, phenylmethyl ester (Benzyl

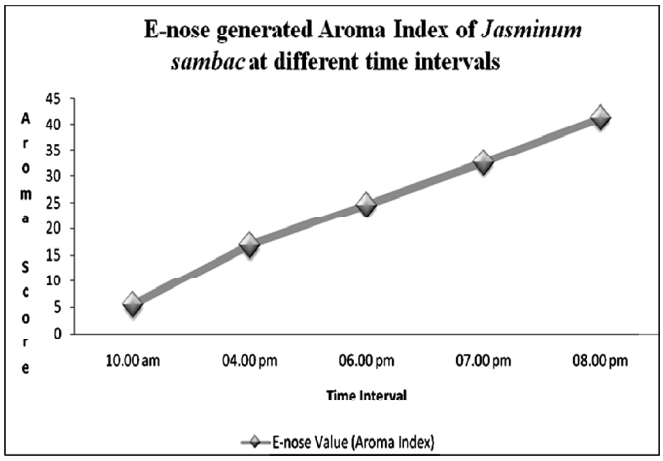

Figure 7: Aroma –Index

stearate) (14.04%). The jasmine volatile compounds responsible for its unique fragrance were released during this time.

The jasmine flower possesses maximum composition during this time. They are Cycloheptasiloxane, tetradecamethyl (7.93%), Cyclohexasiloxane, dodecamethyl (7.22%), Cyclodecasiloxane, eicosamethyl (5.44%) and Heneicosane, 11-(1-ethylpropyl) (5.05%).

Table 6
Comparison Table

Sl. No.	*Compound Name*	*Molecular Weight*	*Timing*	*Retention Area %*
1	Cyclohexasiloxane, dodecamethyl-	444	10 AM	0.23
			6 PM	0.26
			10 PM	7.22
2	Cycloheptasiloxane, tetradecamethyl-	518	10 AM	0.23
			6 PM	0.29
			10 PM	7.93
3	Hexadecamethyl cyclooctasiloxane	592	10 AM	0.17
			6 PM	0.19
			10 PM	4.94
4	Cyclohexasiloxane, eicosamethyl-	740	10 AM	0.15
			6 PM	0.17
			10 PM	3.24

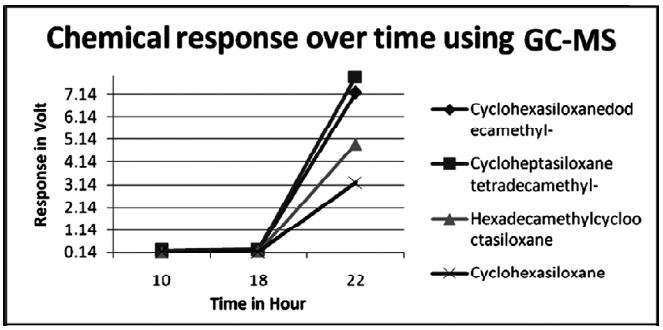

Figure 8: Response of chemicals through GC-MS analysis

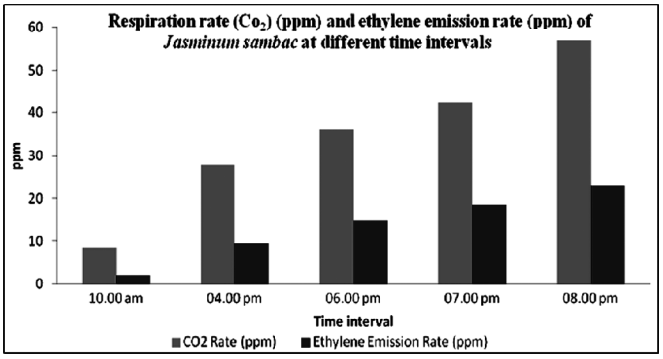

Figure 9: Respiration Rate

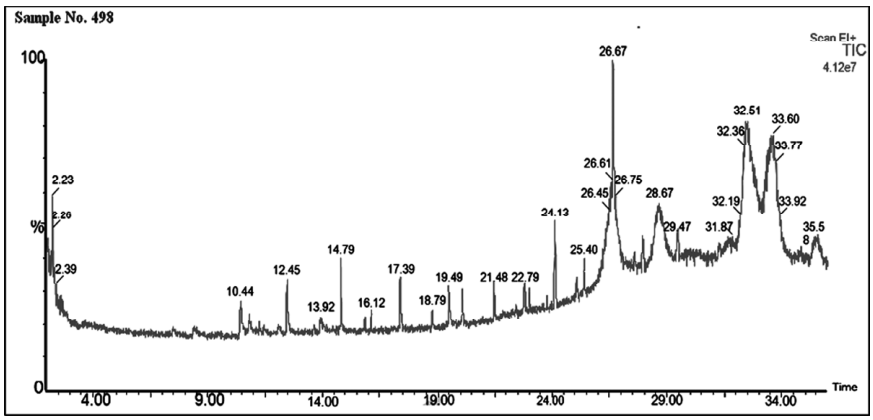

Figure 10: GC-MS Chromatogram of *Jasminium sambac* extract (soxhlet extraction) at 10.00 AM

Table 7
GC-MS analysis of *Jasminum sambac* extract (soxhlet extraction) at 10.00 AM

S. No.	RT	Name of the compound	Molecular Formula	MW	Peak Area %
1.	2.23	2,6-Octadien-1-ol, 3,7 dimethyl-(Z)- (cis-Geraniol)	$C_{10}H_{18}O$	154	14.24
2.	10.44	2-Aminononadecane	$C_{19}H_{41}N$	283	1.23
3.	10.82	Cyclooctyl alcohol	$C_8H_{16}O$	128	0.57
4.	12.45	1-Tetracosanol	$C_{24}H_{50}O$	354	1.51
5.	13.92	1-Methyldodecylamine	$C_{13}H_{29}N$	199	0.38
6.	14.76	2,4,6,8-Tetramethyl-1-undecene	$C_{15}H_{30}$	210	1.49
7.	15.80	Octodrine	$C_8H_{19}N$	129	0.26
8.	16.10	Heptadecane, 2-methyl-	$C_{18}H_{38}$	254	0.35
9.	17.39	1-Hexacosanol	$C_{26}H_{54}O$	382	1.06
10.	18.79	Heptadecane, 2,6,10,15-tetramethyl-	$C_{21}H_{44}$	296	0.31
11.	19.49	Didodecyl phthalate	$C_{32}H_{54}O_4$	502	1.07
12.	20.09	Decane, 2,3,5,8-tetramethyl-	$C_{14}H_30$	198	0.76
13.	21.48	6H-Pyrazolo[1,2 a][1,2,4,5]tetrazine, hexahydro-2,3-dimethyl-	$C_7H_{16}N_4$	156	0.67
14.	22.44	2-Nonen-1-ol	$C_9H_{18}O$	142	0.17
15.	22.79	Octadecane, 6-methyl-	$C_{19}H_{40}$	268	0.76
16.	23.01	2,6,10-Dodecatrien-1-ol, 3,7,11-trimethyl- (Farnesol)	$C_{15}H_26O$	222	0.37
17.	23.79	1-Eicosanol	$C_{20}H_{42}O$	298	0.09
18.	24.13	Nonadecane, 2-methyl-	$C_{20}H_{42}$	282	1.54
19.	25.40	Tetracontane, 3,5,24-trimethyl-	$C_{43}H_{88}$	604	0.86
20.	26.67	Nonadecane	$C_{19}H_{40}$	268	17.41
21.	27.95	Octadecane, 1-(ethenyloxy)-	$C_{20}H_{40}O$	296	0.94
22.	28.67	1-Octadecyne	$C_{18}H_{34}$	250	2.53
23.	29.47	Z,Z-2,5-Pentadecadien-1-ol	$C_{15}H_{28}O$	224	0.92
24.	32.51	9-Octadecenoic acid (Z)-, phenylmethyl ester (Benzyl oleate)	$C_{25}H_{40}O_2$	372	24.04
25.	33.60	Eicosanoic acid, phenylmethyl ester (Benzyl icosanoate)	$C_{27}H_{46}O_2$	402	26.47

Table 8
GC-MS analysis of *Jasminum sambac* extract (soxhlet extraction) at 08.00 PM

S. No.	RT	Name of the compound	Molecular Formula	MW	Peak Area %
1.	2.21	2,6-Octadien-1-ol, 3,7 dimethyl-(Z)- (cis-Geraniol)	$C_{10}H_{18}O$	154	3.50
2.	2.58	1-Octanol, 2,7-dimethyl-	$C_{10}H_{22}O$	158	3.01
3.	3.51	Cyclopropyl carbinol	C_4H_8O	72	3.83
4.	10.80	Cyclooctyl alcohol	$C_8H_{16}O$	128	1.44
5.	14.76	2,4,6,8-Tetramethyl-1-undecene	$C_{15}H_{30}$	210	0.15
6.	15.80	Octodrine	$C_8H_{19}N$	129	0.42
7.	16.10	Heptadecane, 2-methyl-	$C_{18}H_{38}$	254	0.54
8.	17.44	1-Hexacosanol	$C_{26}H_{54}O$	382	0.22
9.	18.79	Heptadecane, 2,6,10,15-tetramethyl-	$C_{21}H_{44}$	296	0.42
10.	19.48	Didodecyl phthalate	$C_{32}H_{54}O_4$	502	0.96
11.	20.16	Decane, 2,3,5,8-tetramethyl-	$C_{14}H_30$	198	0.62
12.	21.14	Octadecanoic acid, phenylmethyl ester (Benzyl stearate)	$C_{25}H_{42}O_2$	374	14.04
13.	21.51	6H-Pyrazolo[1,2 a][1,2,4,5]tetrazine, hexahydro-2,3-dimethyl-	$C_7H_{16}N_4$	156	1.37
14.	22.48	2-Nonen-1-ol	$C_9H_{18}O$	142	0.22
15.	22.85	Octadecane, 6-methyl-	$C_{19}H_{40}$	268	0.93
16.	23.03	2,6,10-Dodecatrien-1-ol, 3,7,11-trimethyl- (Farnesol)	$C_{15}H_26O$	222	0.31
17.	23.66	1-Eicosanol	$C_{20}H_{42}O$	298	0.33
18.	24.16	Nonadecane, 2-methyl-	$C_{20}H_{42}$	282	2.00
19.	25.46	Tetracontane, 3,5,24-trimethyl-	$C_{43}H_{88}$	604	1.08
20.	26.75	Nonadecane	$C_{19}H_{40}$	268	2.41
21.	28.05	Octadecane, 1-(ethenyloxy)-	$C_{20}H_{40}O$	296	0.86
22.	28.63	1-Octadecyne	$C_{18}H_{34}$	250	15.35
23.	28.99	Dodeca-1,6-dien-12-ol, 6,10-dimethyl-	$C_{14}H_{26}O$	210	7.83
24.	29.51	Z,Z-2,5-Pentadecadien-1-ol	$C_{15}H_{28}O$	224	13.22
25.	30.47	Heptadecanoic acid, heptadecyl ester	$C_{34}H_{68}O_2$	508	2.41
26.	31.42	1,4-Dioxaspiro[4.5]decane, 8-(methylthio)-	$C_9H_{16}O_2S$	188	0.39
27.	32.76	9-Octadecenoic acid (Z)-, phenylmethyl ester (Benzyl oleate)	$C_{25}H_{40}O_2$	372	21.01
28.	33.63	Eicosanoic acid, phenylmethyl ester (Benzyl icosanoate)	$C_{27}H_{46}O_2$	402	1.13

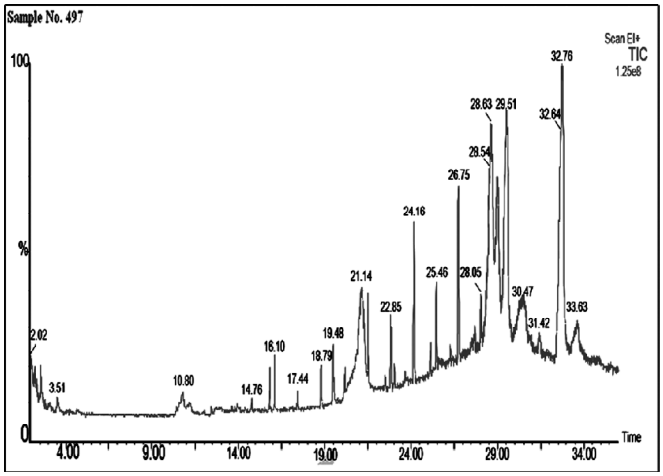

Figure 11: GC-MS Chromatogram of *Jasminium sambac* extract (soxhlet extraction) at 08.00 PM

CONCLUSION

The study of ideal harvesting stage for Jasminum sp. fresh flowers reveals, that the e nose instrument aids in identifying the ideal harvesting stage for fresh flower stage and suitable time for concrete extraction results in fragrance emission. This ultimately helps in industrial utility to identify the perfect stage and time for higher concrete recovery. The identified constituents from jasmine concrete were responsible for their unique fragrance. Considering the bulk of the components eluted under these chromatographic conditions, and assuming these compounds possesses a response for fragrance exclusive for jasmine species.

The quantum emission of fragrance of harvested flowers showed increasing trends from morning to evening. Handheld Electronic Nose (HEN) also shows the absolute identical fragrance pattern. The highest fragrance emission was found during 6.30 pm to 7.00pm. Correlative study of fragrance emission pattern using the HEN and GC-MS showed encouraging results for quality estimation of Jasmine flower using fast, non-invasive, portable electronic device.

REFERENCES

Abdul Khader, JBM MD and N. Kumar, (1995), Genetic resources of jasmine, *Advances in Horticulture*, Vol. 12, Ornamental Plants (Eds.) Chadha, K. L. and S. K. Bhattacharjee, Malhotra Publishing house, New Delhi. Pp. 121-132.

Aishima T., (1991), Aroma discrimination by pattern recognition analysis of responses from semiconductor gas sensor array, *J. Agric. Food Chem*., **39:** 752-756.

Ambasta S. P., (1986), In: Ambasta SP (ed), The Useful Plants of India (pp. 301), *Publication and Information Directorate*, CSIR, New Delhi.

Baker J. E., C. Y. Wang, M. Lieberman and R. Hardenburg, (1977) Delay of senescence in carnation by a rhizobitoxine analog and Na- benzoate, *Hort. Sci.*, **12:** 38-39.

Bose T. K. and S. P. S. Raghava, (1975), Low temperature prolongs the storage life of *South African J. Bot* jasmine flower, *Sci. and Cult.*, **41:** 115-116.

Burger L., G. H. Swardt and A. H. P. Engelbrecht, (1986), Relationship between changes in membrane permeability, respiration rate, activities of lipase and phospholipase and ultra structure in senescing petal of Dianthus., **52(3):** 195-200.

Borochov A., H. Spiegelstein and P. Hadas, (1997), Ethylene and flower petal senescence interrelation ship with membrane lipid metabolism, *Physiol. Plant.*, **100(3):** 606-612.

Chadha Y. R., (1976), In: Chadha Y. R., (ed), The Wealth of India, Raw Materials (pp. 279), *Publication and Informaton Directorate*, CSIR, New Delhi.

Chaudry A. N., Hawkins, T. M., and Travers P. J., (2000), A method for selecting an optimum sensor array, *Sens. Actuators B*, **69:** 236-242.

Chao Chia H., P. Meihwei, W. Tsutsuen, C. C. Huang, M. H. Pan, and T. T. Wang, (1991), Senescence, ethylene production and electrolyte leakage of different parts of chilled *Phalaenopsis* flower, *J. Agric. Res. Of China,* **46(2):** 167-180.

Chezhiyan N., V. Ponnuswamy, S. Thamburaj and J. M. A. Khader, (1984), Evaluation of certain hybrid progenies of *Jasminum auriculatum. South Indian Hort*., **32(1):** 223-228.

Coorts G. D., (1973), Internal metabolic changes in cut flowers, *Hort. Sci*., **8:** 195-198.

Dimri B. P., M. N. A. Khan and G. Rasool, (1976), Prospects of cultivation of jasmine (*Jasminum grandiflorum* Linn.) in South India; A study of flowering and yield, *Indian Perfumer*, ***20(1):*** 23-27.

Gulati B. C., (1960), Cultivation of jasmine, *Indian Oil Soap J.,* **25(7):** 235-240.

Hanson A. D. and H. Kende, (1975), Ethylene enhanced ion and sucrose efflux in morning glory flower tissue, *Plant Physiol.*, **55:** 663-669.

Indian Horticulture database, (2013), *Indian Council of Agricultural Research*, New Delhi.

Indresh K. M. and A. A. Farooqi, (1991), Genetic variations of morphological and floral characters in the open pollinated seedling progenies of *Jasminum auriculatum* Vahl, *Indian Perfumer*, **35(4):** 248-254.

Ishihara Y., K. Ohkawa and H. Hyodo, (1991), Senescence of cut sweet pea flowers and ethylene production, *J. Jap. Soc. Hort. Sci.,* **60(1):** 141-147.

Kaltaler R. E. L. and P. L. Steponkus, (1976), Factors affecting respiration in cut roses, *J. Amer. Soc. Hort. Sci*., **101:** 352-354.

Khan W. M. A., S. Muthuswamy and K. R. Raman, (1970), An evaluation of morphological variations of economic value in *Jasminum sambac. South Indian Hort.,* **18(1):** 25-32.

Lukaszewski T. A. and M. S. Reid, (1989), Bulb type flower senescence, (1989), *Acta Hort.,* **261:** 59-62.

Madhu G. R., (1999), Studies on the effect of different packaging materials and chemicals on the post harvest life of jasmine flowers, *M.Sc. (Ag.) thesis*, Annamalai Univeristy, Annamalainagar, TamilNadu, India.

Maxie E. C., D. S. Farnhano, F. G. Mitchell and N. F. Sommer, (1973), Temperature and ethylene effects on cut flowers of carnation (*Dianthus caryophyllus*), *J. Amer. Soc. Hort. Sci.,* **98(6):** 568-572.

Mayak S. and A. H. Halevy, (1974), The action of kinetin in improving the water balance and delaying senescence processes of cut rose flowers, *Physiol. Plant.,* **32:** 330-336.

Mishra S. D., B. K. Gaur, V. W. Bedeker and B. B. Singh, (1976), Isolation, identification and significance of free radicals in senescing leaves, *Acta Botanica,* **4:** 131-138.

Mukhopadhyay T. P., T. K. Bose, R. G. Maiti, S. K. Misra and J. Biswas, (1980), Effect of chemicals on the post harvest life of jasmine flowers, *National Seminar on Production Technology of Commercial Flower Crops*, TamilNadu Agricultural University, Coimbatore, pp. 47-50.

Naidu S. N. and M. S. Reid, (1989), Postharvest handling of tuberose (*Polianthes tuberosa* L.). *Acta Hort.,* **261:** 313-317.

Raman K. R., (1973), Studies on jasmine with particular reference to flowering, *Ph.D. Thesis* submitted to Tamil Nadu Agricultural University, Coimbatore-3.

Rangaswami P. and M. D. A Khader, (1989), Growth analysis of *Jasminum* spp, *South Indian Hort.,* **37(6):** 367.

Redman B. Paul, John M. Dole, Niels O. Maness and Jeffrey A. Anderson, (2002), Post harvest handling of nine speciality cut flower species, *Scientia Hort.,* **92:** 293-303.

Rogers M. N., (1973), An historical and critical review of post harvest physiology research on cut flowers, *Hort Sci.,* **8:** 189-194.

Suttle J. C. and H. Kende, (1978), Ethylene and senescence in petals of *Tradescantia*. *Plant Physiol.,* **63:** 267-271.

Suttle J. E. and Kende H., (1980), Ethylene action and loss of membrane integrity during petal senescence in Tradescantia, *Plant Physiol.,* **65:** 1067-1072.

Ten Have, A., and E.J. Woltering. 1997. Ethylene biosynthetic genes are differentially expressed during carnation (*Dianthus caryophyllus* L.) flower senescence. *Plant Mol. Biol., 34*: 89-97.

Trippi. V. and A. Paulin. 1984. The senescence of cut carnation. A Phasic phenomenon. *Physiol. Plant., 60*: 221-226.

Vandoorn W. G. and M. S. Reid, (1992), Role of ethylene in flower senescence of *Gypsophila paniculata* L. *Post Harvest Biol. and Tech.,* **1(3):** 265-272.

Veen H., (1983), Silver thiosulphate: an experimental tool in plant science, *Scientia Hort.,* **20:** 211-224.

Wills R., B. McGlasson, D. Graham and D. Joyce, (1998), Postharvest: an introduction to the physiology and handling of fruit, vegetables and ornamentals, *4th ed. UNSW press*, Sydney.