Volatiles Emitted from Flowers of γ-Radiated and Nonradiated *Jasminum polyanthum* Franch. *in Situ*

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Volatile compounds emitted from flowers of *Jasminum polyanthum* Pepita *in situ* were collected by dynamic headspace technique and analyzed by GC−FID and GC−MS. A total of 32 compounds were identified. The flower scent was dominated by benzyl acetate (57.8%), *p*-cresol (12.2%), (*E*)-isoeugenol (9.7%), eugenol (3.5%), 2-methoxy-*p*-cresol (3.1%), linalool (3.0%), phenethyl acetate (2.1%), and (*Z*)-3-hexenyl butyrate (1.9%). The strong scent of Pepita reduces its production potentialities as a pot plant, thus the possibility to reduce or modify the emission of volatiles from Pepita by mutagenesis was investigated. The average total yields of volatiles in Pepita were approximately 2800 ng flower^{-1} h^{-1}, and in one γ-radiated clone a significantly lower yield of 1050 ng flower^{-1} h^{-1} was found. The volatile profiles of the γ-radiated plants were made up of the same 32 compounds found in Pepita. Significant differences in the headspace composition between Pepita and γ-radiated plants were found for some of the major volatiles.

Keywords: *Jasminum polyanthum; Oleaceae; dynamic headspace; flower fragrance; flower volatiles; mutagenesis*

INTRODUCTION

The genus *Jasminum* (Oleaceae) comprises about 200 species, which are widely distributed in East and South Asia, Africa, and Australia. Jasmines are cultivated in Asia for garden decoration and flavoring of tea. In Europe and North Africa, jasmines (mainly *J. grandiflorum*) are cultivated primarily for use in cosmetics. In Asia, *J. auriculatum* and *J. sambac* are also used for this purpose (Mukhopadhyay and Karihaloo, 1989). Consequently, chemical investigations of *Jasminum* species have mainly concerned essential oils, e.g., solvent extracts or steam distillates of flowers (Lavigne et al., 1979; Nofal et al., 1981; Verzele et al., 1981; Wu et al., 1981; Sun et al., 1985; Kaiser, 1988; Musalam et al., 1988; Gopalakrishnan and Narayanan, 1991; Shaath et al., 1992; Joulain and Laurent, 1995). About 70 volatile compounds are reported from the genus *Jasminum*, and these include aliphatic short-chain hydrocarbons, esters, alcohols and aldehydes, terpenoids, as well as aromatic and nitrogenous compounds. Mookherjee et al. (1990) have shown that the aroma of, e.g., jasmine flowers may change soon after they are cut from the plant. Hence, the headspace obtained from picked flowers does not necessarily replicate the aroma of the living material. It is therefore essential to collect the volatile compounds *in situ* if one wish to determine the "true" composition of the emitted aroma from the living plant. A few investigations have been carried out to describe the headspace volatiles emitted from fresh flowers of *Jasminum*, e.g., *J. sambac* (Zhu et al., 1984; Bu et al., 1987; Kaiser, 1988), *J. officinale* (Joulain, 1987), and *J. grandiflorum* (Mookherjee et al., 1990). However, only the investigation of the latter was carried out *in situ*.

Jasminum polyanthum Franch., a native of southwest China, has in recent years become popular as a pot plant because it produces a mass of white flowers with a delicious fragrance. However, as with other strongly scented flowers some people find the scent of *J. polyanthum* "overpowering", with the prolonged sensory stimulation by the volatiles emitted causing headaches and nausea. The popularity of *J. polyanthum* as a pot plant may be increased if cultivars with a less strong scent could be developed. Mutation breeding may be an effective method to reduce the scent as it is possible by mutagenesis to change a few genes without altering the total genetic makeup. Thus mutagenesis is especially useful when an outstanding cultivar has to be corrected in a specific characteristic. Production of chemical compounds in plants have been altered in, e.g., *Mentha* species, tea (*Camellia sinensis*), and lemongrass (*Cymbopogon flexuosus*) by mutagenesis (Broertjes and van Harten, 1988).

The purpose of the present study was to describe the qualitative and quantitative *in situ* emission of volatiles from *J. polyanthum* Franch. Pepita flowers. Furthermore, the aim was to determine whether the emission of volatiles from *J. polyanthum* could be reduced or modified by mutagenesis.

EXPERIMENTAL PROCEDURES

Mutagenesis and Plant Growth. To induce mutations, the lethal dose of γ-rays from a ^{60}Co source for newly rooted cuttings of *J. polyanthum* Franch. Pepita was determined by radiation with doses of 0−80 gray. The highest dose allowing lateral buds to develop was 25 gray, and this dose was then used to radiate a larger number of cuttings. After radiation, developing shoots were pinched twice to reduce chimerism. Leaf-bud cuttings were then taken from developing shoots and rooted in fertilized peat under plastic in 8 cm pots, one cutting

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per pot. After root formation and growth for 3 months at minimum 20 °C, the temperature was reduced to minimum 12 °C for flower induction. In order to regulate the flower development plants were moved to minimum 5 °C until measurements. Sixty plants were selected on the basis of morphological characteristics such as number of flowers, inflorescences, and plant size, comparable with control plants (Pepita). These plants were subjected to preliminary headspace analysis, and the five most promising plants, regarding the lowest total emission of volatiles, and Pepita were then cloned into 3−5 plants and grown as described above. The five selected clones, numbered Jp-1, Jp-2, Jp-3, Jp-4, and Jp-5, and Pepita (control) were then used for further headspace analysis. Four days prior to sampling, plants were moved to a room with artificial light allowing the plants to acclimatize. The artifical light was supplied by a 400 W HPI-T lamp, suitable when used as the only light source. Heat radiation from the lamp was reduced using a water screen as described by Jakobsen (1997). The plants were subjected to a 16 h photoperiod starting at 8 a.m. The temperature was 20 °C, and the relative air humidity was not controlled.

Collection of Volatiles. Volatiles were collected as described by Jakobsen and Olsen (1994) and Jakobsen et al. (1994), with a few alterations. One inflorescence with 10−25 open flowers was measured in each trial. In order to prevent damage on the flowers when guiding them through a socket in the inverted lid below the glass bulb, flowers were guided through the socket at an early development stage and allowed to develop above the inverted lid for several days before sampling (Jakobsen, 1997). Headspace samples from the empty glass bulb containing sealing material (Terosan, Heidelberg, FRG) were collected in order to test for impurities. The air flow in the glass bulb was 200 mL min^{-1}, and the vacuum in the vessel was 0.8 kPa. Volatiles were collected in glass tubes (3 mm i.d., length 18 cm) equipped with 100 mg of Porapak Q 50−80 mesh (Waters Inc., Milford, MA) inserted between two silane-treated glass wool plugs. The collection time on each column was 2 h starting at 11 a.m. Volatiles were eluted from the Porapak columns with 2 mL of redistilled pentane. For quantification, nonanal (830 ng in 10 μL pentane) was added to the headspace samples prior to careful evaporation of excess solvent under nitrogen flow to a final volume of 50 μL.

Analysis of Volatiles. A Hewlett-Packard 5890 gas chromatograph (GC) (Hewlett-Packard, Avondale, PA) equipped with a flame ionization detector (FID) was used. Volatiles were separated on a 50 m × 0.20 mm (i.d.) HP-wax column (d_f = 0.40 μm; HP part no. 19091x-205). The oven temperature was programmed to be isothermal for 1 min at 30 °C and to increase from 30 to 120 °C at a rate of 5 °C min^{-1}, to increase from 120 to 220 °C at a rate of 10 °C min^{-1}, and subsequently to remain isothermal at 220 °C for 50 min. Helium carrier gas was used at a flow rate of 1 mL min^{-1} with a splitless purge time of 75 s. The injection temperature was 220 °C, and the FID temperature was 240 °C. Yields of individual volatiles in the Porapak eluates were estimated from FID peak areas of components and the standard, nonanal, used in the GC analyses. The response factor was set to 1 for all compounds.

GC−MS analyses were performed on a Varian gas chromatograph, interfaced with an SSQ 710 Finnigan MAT single-quadrupole mass spectrometer operated in electron ionization mode at 70 eV. The GC conditions were the same as described above. For identification, MS and GC retention data for headspace components were compared to those for authentic compounds (Table 1). GC retention indices (Kovats index) were determined externally with a series of *n*-alkanes (C_9−C_{25}) (van den Dool and Kratz, 1963; Farkas et al., 1994). The GC conditions were the same as described above with the exception of the oven temperature which was approximately linearly programmed: 30 °C (1 min isothermal) to 220 °C at 5 °C min^{-1} and subsequently isothermal at 220 °C in 30 min. Authentic compounds were supplied by Aldrich (Steinheim, Germany) and by TCI Tokyo Organic Chemicals (Japan).

GC−Sniffing Technique. A Shimadzu 14A gas chromatograph equipped with a 60 m × 0.25 mm (i.d.) HP-Innowax column (d_f = 0.25 μm; HP part no. 19091N-136) was used. The oven temperature was programmed to be isothermal for 1.5 min at 32 °C, to increase from 32 to 120 °C at a rate of 5 °C min^{-1}, then from 120 to 220 °C at a rate of 10 °C min^{-1}, and then remain isothermal at 220 °C for 30 min. Helium carrier gas was used at a flow rate of 1 mL min^{-1}. The injection temperature was 220 °C, and the FID temperature was 240 °C. GC−sniffing evaluation of individual compounds was performed on a SGE OSS-2 splitter system with humid air purging and helium make-up gas (20 mL min^{-1}).

Statistical Treatment. Values in Table 2 are expressed as the mean ± standard error. Comparisons between controls and γ-radiated plants were performed using Student's *t*-test. *P* values below 0.05 were considered significant. All measurements were repeated 3 times or more.

RESULTS AND DISCUSSION

The 32 compounds identified from the headspace samples of *J. polyanthum* Franch. Pepita are listed in Table 1 along with their characteristic MS fragments and retention indices. The predominant class in terms of their total amounts was aromatics. Fatty acid derivatives comprised aliphatic hydrocarbons, alcohols, aldehydes, and esters. The third class of compounds identified was terpenes and included hydrocarbons, alcohols, ketones, and esters. Several minor/trace compounds were not identified.

The quantitative contribution of the individual compounds to the floral fragrance of *J. polyanthum* Pepita is given in Table 2 (column "Pepita"). Benzenoids and phenylpropanoids constituted the major part of the fragrance emitted, with benzyl acetate (57.8%) as the major contributor, followed by *p*-cresol (12.2%), (*E*)-isoeugenol (9.7%), eugenol (3.5%), 2-methoxy-*p*-cresol (3.1%), phenethyl acetate (2.1%), and benzyl alcohol (1.0%). The compounds (*E*)-methyl cinnamate, (*Z*)-isoeugenol, phenethyl alcohol, and methyl benzoate were only present in minute amounts in the headspace (Table 2). The aromatic compounds emitted from the flowers of *J. polyanthum* have previously been isolated from essential oils and/or headspace of *Jasminum* (Lavigne et al., 1979; Nofal et al., 1981; Wu et al., 1981; Verzele et al., 1981; Sun et al., 1985; Kaiser, 1988; Musalam et al., 1988; Mookherjee et al., 1990; Gopalakrishnan and Narayanan, 1991; Joulain and Laurent, 1995). However, the presence of (*E*)- and (Z)-isoeugenol, 2-methoxy-*p*-cresol, (*E*)-methyl cinnamate, phenethyl acetate, and phenethyl alcohol in *J. polyanthum* is, to the best of our knowledge, the first report of these compounds in headspace analysis of this genus. Nearly all of the aromatic compounds have previously been reported in floral scents from other genera, and especially benzyl acetate, benzyl alcohol, phenethyl alcohol, phenethyl acetate, methyl benzoate, (*E*)-methyl cinnamate, and eugenol seem to be common fragrance constituents (Knudsen et al., 1993).

Fatty acid derivatives constituted about 5.2% of the total fragrance emitted from the flowers, of which the aliphatic esters were the most abundant in terms of numbers and total amounts (Table 2). (*Z*)-3-Hexenyl acetate and (*Z*)-3-hexenyl butyrate have previously been detected in the headspace of *Jasminum* (Zhu et al., 1984; Bu et al., 1987; Mookherjee et al., 1990), whereas the presence of the *E*-isomers of 2-hexenyl acetate and 2-hexenyl butyrate in *J. polyanthum* is the first report of these compounds in headspace samples of this genus, although they have been found in solvent extracts or steam distillates (Verzele et al., 1981; Musalam et al., 1988). (*Z*)-3-Hexenol is a well-known headspace com-

Table 1. Compounds Identified in Flower Headspace Samples from *J. polyanthum* Pepita

compound[a]	mass spectral ions (relative abundance in %)[b]								KI[c]
fatty acid derivatives									
isobutyl acetate	43 (100)	56 (35)	73 (23)	86 (4)					993
isopropyl butyrate	43 (100)	71 (73)	89 (35)	59 (13)	115 (12)				1024
hexanal	56 (100)	44 (95)	41 (80)	43 (50)	82 (25)	72 (20)	**100** (1)		1077
(*E*)-2-hexenal	41 (100)	55 (83)	69 (80)	83 (69)	**98** (28)				1231
(*Z*)-3-hexenyl acetate	43 (100)	67 (85)	82 (71)						1328
(*E*)-2-hexenyl acetate	43 (100)	67 (37)	82 (34)	100 (21)	**142** (1)				1344
(*Z*)-3-hexenol	67 (100)	41 (81)	82 (57)	55 (38)	69 (25)	**100** (4)			1396
(*Z*)-3-hexenyl butyrate	82 (100)	67 (98)	71 (74)	43 (49)	41 (24)	55 (14)			1473
(*E*)-2-hexenyl butyrate	71 (100)	43 (36)	67 (31)	82 (25)	55 (22)	41 (20)	**170** (2)		1485
hexadecane	57 (100)	71 (74)	43 (71)	85 (57)	99 (15)	113 (8)	**226** (10)		1600
heneicosane	57 (100)	71 (80)	43 (66)	85 (66)	99 (23)	113 (16)	**296** (7)		2100
docosane	57 (100)	71 (79)	43 (70)	85 (64)	99 (25)	113 (19)	**310** (6)		2200
tricosane	57 (100)	71 (80)	43 (69)	85 (66)	99 (24)	113 (18)	**324** (5)		2300
pentacosane	57 (100)	71 (80)	43 (69)	85 (66)	99 (25)	113 (18)	**352** (4)		2500
benzenoids									
methyl benzoate	105 (100)	77 (51)	**136** (46)	51 (15)					1654
benzyl acetate	108 (100)	91 (52)	**150** (45)	43 (27)	79 (23)	77 (15)	65 (11)		1767
phenethyl acetate	104 (100)	43 (33)	91 (15)	65 (5)	77 (5)				1849
benzyl alcohol	79 (100)	**108** (98)	107 (74)	77 (57)	51 (17)	91 (11)	65 (7)		1907
phenethyl alcohol	91 (100)	92 (50)	**122** (42)	65 (18)	51 (7)	77 (6)			1946
2-methoxy-*p*-cresol	**138** (100)	123 (85)	95 (23)	67 (12)	77 (12)	55 (9)			1996
p-cresol	107 (100)	**108** (76)	77(20)	79 (16)	90 (7)				2117
phenylpropanoids									
(*E*)-methyl cinnamate	131 (100)	**162** (66)	103 (51)	77 (31)	51 (15)				2125
eugenol	**164** (100)	149 (31)	131 (23)	103 (21)	77 (18)	137 (16)	91 (15)	121 (13)	2210
(*Z*)-isoeugenol	**164** (100)	149 (33)	103 (19)	131 (18)	77 (18)	91 (16)	121 (12)	133 (10)	2298
(*E*)-isoeugenol	**164** (100)	149 (31)	103 (18)	131 (18)	77 (16)	91 (15)	121 (12)	133 (12)	2394
terpenoids									
6-methyl-5-hepten-2-one	43 (100)	108 (55)	41 (43)	69 (34)	55 (30)	111 (22)	**126** (11)		1352
linalool	71 (100)	93 (81)	55 (50)	43 (49)	41 (45)	69 (39)	121 (27)	136 (11)	1557
β-caryophyllene	41 (100)	133 (94)	93 (90)	79 (65)	105 (48)	161 (42)	189 (25)	**204** (12)	1625
(*E*,*E*)-farnesol	69 (100)	93 (76)	41 (52)	43 (49)	107 (47)	136 (33)	161 (29)	189 (6)	2051
(*E*,*E*)-farnesyl acetate	69 (100)	93 (37)	43 (36)	81 (34)	136 (31)	161 (9)	189 (7)	**264** (2)	2280
miscellaneous									
jasmin lactone	99 (100)	71 (76)	55 (33)	43 (25)	41 (23)	**168** (8)			2318
indole	**117** (100)	90 (32)	89 (26)	63 (7)	59 (4)				>2500

[a] Identification of plant components is based on comparison of their mass spectral data with those from authentic compounds and on mass spectra of compounds suggested by the NIST database (NIST, 1992). GC retention data of each plant component were verified by comparison with those from authentic compounds. [b] Fragmentation ions, base peak, and characteristic ions in decreasing order of relative abundance. Molecular ions in boldfaced type. [c] Kovats index determined on a 50 m × 0.20 mm HP-wax column.

ponent, whereas the aldehydes hexanal and (*E*)-2-hexenal seem to be rare in floral scents (Knudsen et al., 1993). Within the genus *Jasminum*, hexanal and (*E*)-2-hexenal have only been detected in steam distillates of *J. grandiflorum* (Verzele et al., 1981). Aliphatic long-chain hydrocarbons are well-known constituents of the cuticular waxes covering the stems, leaves, and flowers of most plants (Kolattukudy, 1980); thus the aliphatic hydrocarbons detected in the headspace of *J. polyanthum* probably originate from these sources.

The terpenoids emitted from the flowers constituted about 3.8% of the total fragrance of which the monoterpene linalool was the most abundant (Table 2). Linalool has been found in the headspace of many genera, including *Jasminum* and may be considered as a common floral fragrance constituent. The other terpenoids detected were only present in very minute amounts, and with the exception of (*E*,*E*)-farnesyl acetate they have all been found in the floral headspace of *Jasminum* species (Knudsen et al., 1993).

The miscellaneous compounds consisted of only two components, jasmin lactone [5-(*Z*)-2-pentenyl-5-pentanolide] and indole (Table 2). Indole is known to be a common constituent in the genus *Jasminum*, and normally it appears in large quantities in headspace and in essential oils. It is considered to be a major contributor to the fragrance of *Jasminum* species (Verzele et al., 1981; Sun et al., 1985; Mookherjee et al., 1990). Surprisingly, we only found this component in very minute amounts (Table 2). Jasmin lactone is a common constituent in essential oils from flowers of jasmines (Verzele et al., 1981) but has not previously been detected in the floral headspace of *Jasminum* species.

Most of the aromatic compounds encountered have rather strong odors, and especially the esters are regarded as possessing floral notes. Sniff analysis of the headspace volatiles showed that the major compounds, linalool (sweet, floral), benzyl acetate (sweet, fruity, floral, jasmin), *p*-cresol (heavy, phenolic), (*E*)-isoeugenol (sweet, spicy, clove, vanilla), eugenol (sweet, spicy, clove), 2-methoxy-*p*-cresol (sweet, vanilla, phenolic), and phenethyl acetate (floral), are contributing significantly to the fragrant of *J. polyanthum*. Further, compounds such as (*Z*)-3-hexenol (green grass), (*Z*)-3-hexenyl acetate (green, fruity), (*Z*)-3-hexenyl butyrate (fruity, floral), and benzyl alcohol (floral) also seem to have an influence on the flower fragrance. The volatiles indole, β-caryophyllene, methyl benzoate, and jasmin lactone are known to have strong odors, but, probably due to their very minute amounts, they had no major influence on the flower fragrance of *J. polyanthum* as perceived via the GC−sniffing.

Some of the major scent constituents have biological effects. Eugenol and (*E*)-isoeugenol can cause allergic contact dermatitis; they are, for example, the major allergens in *Syzygium aromaticum* (L.) Merrill et Perry (Hausen, 1988). Jasmine oil can also cause allergic contact dermatitis, and benzyl acetate is suspected to be one of the allergens (Hausen, 1988). Furthermore, benzyl acetate, *p*-cresol, and 2-methoxy-*p*-cresol are

Table 2. Yields of Flower Headspace Volatiles Emitted *in Situ* by *J. polyanthum* Pepita and Five γ-Radiated Specimens

compound	floral emission in %[a]					
	Pepita	Jp-1	Jp-2	Jp-3	Jp-4	Jp-5
fatty acid derivatives						
isobutyl acetate	0.6 ± 0.3	0.6 ± 0.1	1.1 ± 0.1	0.6 ± 0.1	1.0 ± 0.2	0.6 ± 0.1
isopropyl butyrate	trace[b]	0.1 ± 0.0	0.2 ± 0.1	0.1 ± 0.0	0.2 ± 0.1	trace
hexanal	trace	trace	trace	trace	trace	0.2 ± 0.0
(*E*)-2-hexenal	0.4 ± 0.3	trace	trace	trace	0.1 ± 0.1	trace
(*Z*)-3-hexenyl acetate	0.8 ± 0.5	1.6 ± 0.3	1.6 ± 0.5	1.1 ± 0.5	2.7 ± 0.7	0.7 ± 0.2
(*E*)-2-hexenyl acetate	0.3 ± 0.2	0.6 ± 0.2	0.6 ± 0.2	0.5 ± 0.2	0.8 ± 0.2	0.3 ± 0.1
(*Z*)-3-hexenol	0.7 ± 0.4	1.7 ± 0.5	1.8 ± 0.6	1.2 ± 0.4	2.2 ± 0.9	0.7 ± 0.1
(*Z*)-3-hexenyl butyrate	1.9 ± 1.2	4.9 ± 2.2	6.1 ± 1.5	3.9 ± 1.4	6.7 ± 2.4	2.0 ± 0.5
(*E*)-2-hexenyl butyrate	0.3 ± 0.2	0.8 ± 0.3	0.7 ± 0.1	0.7 ± 0.2	0.8 ± 0.3	0.4 ± 0.1
hexadecane	0.2 ± 0.1	0.4 ± 0.2	0.2 ± 0.1	0.3 ± 0.2	0.1 ± 0.0	0.2 ± 0.0
heneicosane	trace	trace	trace	trace	trace	trace
docosane	trace	trace	trace	trace	trace	trace
tricosane	trace	trace	trace	trace	trace	trace
pentacosane	trace	trace	trace	trace	trace	trace
benzenoids						
methyl benzoate	0.3 ± 0.1	0.4 ± 0.1	0.4 ± 0.1	0.4 ± 0.2	0.3 ± 0.0	0.4 ± 0.1
benzyl acetate	57.8 ± 0.8	55.4 ± 1.7	55.5 ± 6.8	59.6 ± 4.2	61.2 ± 3.8	58.3 ± 5.5
phenethyl acetate	2.1 ± 0.2	2.1 ± 0.6	1.3 ± 0.1[c]	1.0 ± 0.5	1.4 ± 0.2	1.9 ± 0.3
benzyl alcohol	1.0 ± 0.4	0.6 ± 0.2	0.4 ± 0.0	0.5 ± 0.1	0.8 ± 0.1	0.9 ± 0.1
phenethyl alcohol	0.3 ± 0.1	0.4 ± 0.1	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.1	0.3 ± 0.1
2-methoxy-*p*-cresol	3.1 ± 0.1	3.6 ± 0.7	3.5 ± 1.1	3.4 ± 1.5	2.1 ± 0.2[c]	2.8 ± 0.5
p-cresol	12.2 ± 1.7	11.5 ± 0.8	11.8 ± 2.1	10.3 ± 0.3	6.8 ± 0.7[d]	7.7 ± 3.2
phenylpropanoids						
(*E*)-methyl cinnamate	0.4 ± 0.1	0.4 ± 0.1	0.3 ± 0.1	0.8 ± 0.3	0.4 ± 0.1	0.5 ± 0.1
eugenol	3.5 ± 0.5	2.5 ± 0.4	2.9 ± 0.7	1.9 ± 0.4[d]	1.4 ± 0.2[c]	2.5 ± 0.8
(*Z*)-isoeugenol	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.1	0.2 ± 0.0	0.1 ± 0.0[c]	0.2 ± 0.1
(*E*)-isoeugenol	9.7 ± 0.8	7.7 ± 2.4	5.5 ± 1.0[c]	6.0 ± 0.9[c]	4.4 ± 0.3[c]	14.5 ± 5.5
terpenoids						
6-methyl-5-hepten-2-one	trace	trace	0.4 ± 0.2	trace	0.1 ± 0.0	0.2 ± 0.1
linalool	3.0 ± 1.1	3.9 ± 0.6	4.3 ± 0.7	5.8 ± 1.2	5.2 ± 0.8	3.6 ± 0.6
β-caryophyllene	0.1 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.3 ± 0.2	0.2 ± 0.0	0.1 ± 0.0
(*E,E*)-farnesol	0.3 ± 0.1	0.2 ± 0.0	0.2 ± 0.1	0.4 ± 0.2	0.2 ± 0.0	0.6 ± 0.5
(*E,E*)-farnesyl acetate	0.4 ± 0.2	0.2 ± 0.1	0.2 ± 0.1	0.3 ± 0.1	0.1 ± 0.0	0.4 ± 0.2
miscellaneous						
jasmin lactone	0.4 ± 0.3	trace	0.4 ± 0.3	0.5 ± 0.0	0.5 ± 0.3	trace
indole	trace	trace	trace	trace	trace	trace
total	100.0	100.0	100.0	100.0	100.0	100.0
total volatiles entrained in ng flower^{-1} h^{-1}	2754 ± 537	1830 ± 442	2426 ± 237	2735 ± 749	1391 ± 445	1050 ± 206[c]
% identified	~98	~98	~98	~98	~98	~98

[a] Mean of at least three determinations ± standard error. [b] Trace, integrated but the floral emission less than 1 ng flower^{-1} h^{-1}. [c] Significantly different ($P < 0.05$) from that of the control plants (Pepita). [d] Close to 5% significance was found for eugenol in Jp-3 ($P < 0.052$) and for *p*-cresol in Jp-4 ($P < 0.050$) compared to the control plants (Pepita).

irritating to the skin, eyes, and the respiratory tract (*The Merck Index*, 1996). The level of exposure to these constituents by inhalation is most likely below the occupational exposure limits even for a person in close proximity to the plant for several hours. However, a prolonged sensory stimulation by these aromatic volatiles may cause headaches, nausea, or other kinds of hypersensitive reactions. These compounds are therefore supposed to be the main reasons why some people find the scent of *J. polyanthum* "overpowering".

To investigate the possibility for the production of a *J. polyanthum* plant with a reduced scent and a lower level of the most harmful volatiles a *J. polyanthum* Pepita clone was irradiated with γ-rays at time of lateral bud break, with the purpose to create mutations. The results of the headspace analyses of the γ-radiated plants, Jp-1, Jp-2, Jp-3, Jp-4, and Jp-5, and a non-radiated specimen of *J. polyanthum* Pepita are shown in Table 2. The volatile profiles of the γ-radiated plants were made up of the same 32 compounds found in the controls, hence no qualitative differences. The average total volatile yields of the control plants (Pepita) were approximately 2800 ng flower^{-1} h^{-1}, whereas the γ-radiated plants gave volatile yields ranging from 1050 ng flower^{-1} h^{-1} in Jp-5 to 2735 ng flower^{-1} h^{-1} in Jp-3. The total amounts of volatiles emitted from Jp-5 were found to be significantly lower compared to Pepita ($P < 0.05$). The average total volatile yields of the other γ-radiated plants (Jp-1−Jp-4) were not statistically significant at the 5% level. Significant quantitative differences in the headspace composition (i.e., the relative content of each compound) were found, for some of the major headspace components, comparing γ-radiated plants with controls (Table 2). In the γ-radiated clones, Jp-2, Jp-3, and Jp-4, the relative content of (*E*)-isoeugenol was significantly lower than in Pepita, as were phenethyl acetate in Jp-2 and (*Z*)-isoeugenol, eugenol, and 2-methoxy-*p*-cresol in Jp-4. Close to 5% significance was found for eugenol ($P < 0.052$) in Jp-3 and for *p*-cresol ($P < 0.050$) in Jp-4. The fact that the composition of volatiles has changed for biosynthetically related benzenoids and phenylpropanoids in Jp-2, Jp-3, and Jp-4 compared to the control plants could indicate a modification in some of the genes which regulate the biosynthesis of these compounds. However, the lower total volatile yields emitted from Jp-5 cannot be explained by a modification in a few genes, since no significant differences were found in the headspace composition of Jp-5 compared to controls. A possible explanation could be that regulatory mecha-

nisms responsible for the accumulation and release of volatiles in the flowers have been affected by mutation.

Mutagenesis has previously been used to change the chemical composition of some oil crops. In *Mentha arvensis* var. *piperascens*, the composition of the essential oil has been changed so the aroma was quite similar to that of rose oil, and in lemongrass, mutants have been produced which lack methyleugenol, an undesirable compound of the oil (Broertjes and van Harten, 1988). The present results indicate that it is also possible by mutagenesis to make changes in the absolute emission of some of the major volatiles and to reduce the total amounts of volatiles emitted from the flowers of *J. polyanthum* Pepita *in situ*. However, as we only screened 60 γ-radiated plants, which is a relatively small population, it cannot be excluded that a larger population would have yielded mutants being much more significantly different from Pepita. Further investigations may show if it is possible to make greater significant alterations of the floral scent of *J. polyanthum* without changing the characteristics of the aroma dramatically. Reducing the amount of volatiles emitted from strongly scented ornamentals may be important as more people find them unpleasant after a period of time. Mutation breeding may be a way to solve this problem.

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