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Fragrance Composition in Six Tree Peony Cultivars

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Abstract. Tree peony is a traditional famous flower of China, and plays an important role in Chinese traditional culture. But the floral scent of tree peony in vivo is little known. In this study, in order to explore the floral composition of tree peony, floral volatiles of six cultivars, including *Paeonia suffruticosa* 'Zhaofen' (ZF), *P. suffruticosa* 'Luoyanghong' (LYH), *P. ostii* 'Fengdanbai' (FDB), *P. × lemonei* 'High noon' (HN), *P. × lemonei* 'Renown' (R), and *P. rockii* 'Gaoyuanshenghuo' (GYSH) were collected by dynamic headspace and then identified by Automated Thermal Desorption-Gas Chromatography/Mass Spectometry. The results showed that floral fragrances of the six cultivars were qualitatively and quantitatively distinct. A total of 105 volatiles involving ten categories were detected. But not all volatile categories were emitted from these cultivars. The six peony cultivars emitted some shared compounds and peculiar compounds. The total released amounts of volatiles emitted from six cultivars were found significantly different, which was greatest for 'GYSH'. The most abundant volatile compounds detected from 'ZF', 'LYH', 'FDB', 'HN', 'R', and 'GYSH' were respectively α-pinene, 2,3-dihydroxy propanal, 3-methyl-1-butanol, 2-ethyl-1-hexanol, acetic acid 1-methylethyl ester, and 5-ethyl-2,2,3-trimethyl heptane. This result may contribute to exploring the biosynthesis and emission mechanism of floral scent in tree peony.

***Additional key words*:** floral scent, released amount, volatile category, volatile compound

Introduction

Floral scent is an important part of volatile compounds emitted from plants, which acts as an airborne regulator playing a significant role in many ecophysiological processes. Floral fragrances have been found to serve as chemical cues to attract pollinators many years ago (Faegri and van der Pijl, 1979), and this function is also studied most in the subject of floral scent (Stashenko and Martinez, 2008). The present study showed that floral scent was involved in plant defense responses and plant-plant interactions (Arimura et al., 2004; Dudareva et al., 2006; Kaori et al., 2002; Pichersky and Gershenzon, 2002; Ton et al., 2007). Moreover, some floral fragrances were found to be with pleasant and relaxing odor, so could be used to treat some psychological and physiological illnesses medically.

Floral scent is a mixture of volatile compounds, belonging to terpenoids, aromatics, and fatty acid derivatives with low vapours pressure and low molecular weights (Pichersky and Gershenzon, 2002). Significant difference was found in the composition, the released amount, and released rhyme of floral scent (Knudsen and Tollsten, 1993; Knudsen et al., 1993), which determined the particular characteristic fragrance of a flower (Knudsen et al., 1993; Pichersky et al., 1994). And the difference in floral scent could be perceived by insects, resulting in differences in the patterns of pollination and the types of pollinators (Wright et al., 2005). Some components of floral scent were thought to be the insect repellents in the plant defense against insect herbivory (Gershenzon and Croteau, 1991). The existing studies showed that floral scent played a multi-role for the plants, thus the floral scent is in of great ecophysiological significance. So far, floral fragrances of many plants have been investigated, such as *Clarkia breweri* (Raguso and Pichersky, 1995), Silene plants (Jürgens et al., 2002), *Antirrhinum majus* (Wright et al., 2005), *Yucca filamentosa* (Svensson et al., 2005), and wisterias (Jiang et al., 2011) etc.

Tree peony belonging to the family Ranunculaceae, a Chinese-specific woody flower, is called as "king of the flowers" and the flower with "national beauty and heavenly

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fragrance", which has been cultivated artificially for over 2000 years (Chen and Wu, 2005). Though floral scent of peony was examined by the way of solid phase micro-extraction (SPME) and distillation (Li, 2010; Liu, 1999; Zhang, 2011; Zhou, 2008), in these experiments, the flowers used were all in vitro or damaged, which led to changes in the emission profiles (Dudareva and Pichersky, 2000). So floral scent of tree peony in the state of nature was unknown.

In this study, floral fragrances of 6 tree peony cultivars were collected in vivo by dynamic headspace sampling, and then were analyzed using Automated Thermal Desorption-Gas Chromatography/Mass Spectrometry (ATD-GC/MS), which would ensure that the results obtained truly reflected the natural state of tree peony, contributing to comparing aroma composition and released amount among cultivars. Thus it would provide theoretical basis for the further research on the mechanism of flower fragrance formation, and furthermore for the molecular breeding in the field of floral scent.

Materials and Methods

Plant Materials

In this study, 6 tree peony cultivars including *Paeonia suffruticosa* 'Zhaofen' (ZF), *P. suffruticosa* 'Luoyanghong' (LYH), *P. ostii* 'Fengdanbai' (FDB), *P.* × *lemonei* 'High noon' (HN), *P.*× *lemonei* 'Renown' (R), and *P. rockii* 'Gaoyuanshenghuo' (GYSH) were chosen for the floral scent analysis. These plants were grown under a natural photoperiod in the greenhouse of the peony garden in Xishan Experimental Forest Farm of Beijing Forestry University. The collection of floral scent was carried out at 09:00 a.m. with the temperature 22 ± 2℃ in the clear and calm day from the end of April to early May when the peony flowers were in full bloom.

Floral Scent Collection

The dynamic headspace sampling (Raguso and Pellmyr, 1998; Raguso and Pichersky, 1995) was used to collect the floral scent emitted from tree peony. An individual flower was put in a Reynolds oven bag (16 IN × 17.5 IN; washed carefully with alcohol before using) which released and absorbed few volatiles (Hu et al., 2008). A stainless steel tube (0.25 IN × 3.5 IN, USA) containing Tenax-GR (60-80 mesh, Chrompack) was used as the volatile trap, which avoided touching the flower. A portable air sampler (QC-1; Beijing Municipal Institute of Labour Protection, China) was used as the pump and air was filtered through a drying column filled with charcoal. The volatiles were collected for 20 min at a flow rate of 300 $mL\cdot min^{-1}$ for each flower. In the experiment, headspace collection from ambient air was used as a control. Afterward, the stainless steel tubes were sealed and placed in a desiccator.

Floral Scent Analysis

ATD-GC/MS was used to analyze the floral scent. The floral scent collected in the stainless steel tube was desorbed by heating in an ATD (Auto Thermal Desorber, TurboMatrix 650, PerkinEImer) at 260℃ for 10 min, and then cryofocused in a cold trap whose temperature was maintained at -25℃ for 3 min. The cold trap then was heated to 300℃ maintained for 5 min, and the volatiles were transported to GC (Clarus 600, PerkinEImer, Waltham, USA).

The GC was equipped with a capillary DB-5MS column (30 m × 0.25 mm i.d., with a 0.25 μm film thickness). Helium was used as the carrier gas. The GC was programmed at 40℃ for 2 min, $4℃\cdot min^{-1}$ up to 160℃, then $20℃\cdot min^{-1}$ up to 270℃, and held at 270℃ for 3 min.

The MS (Clarus 600T, PerkinEImer, Waltham, USA) was operated in EI ionization mode at 70 ev, and a mass scan range of 29-600 amu was monitored. Interface and ion source temperatures were 250℃ and 220℃, respectively.

Floral Scent Identification and Quantification

Preliminary identification of the compounds was made by searching the NIST08 library in the TurboMass Ver5.4.2 software and checked according to retention index. In order to enable the released amount of volatile components to be compared, alpha-pinene (Fluka, USA) was used as an external standard. As described previously (Hu et al., 2008; Ping et al., 2001) with some modification, the α-pinene was dissolved in ethyl acetate with different solution concentrations including 0.286, 0.858, 1.716, and 8.580 $\mu g\cdot\mu L^{-1}$. 'μg/h/flower' was used as unit to describe the released amount.

Results

Fig. 1 showed the chromatographic profiles of 6 different tree peony cultivars, and significant difference was found. Totally 105 volatile compounds were identified to be emitted from the flowers of these tree peony cultivars. These 105 volatile compounds identified belonged to 10 categories including ester, alcohol, aldehyde, fatty hydrocarbon, benzenoid and derivative, ketone, acid, terpenoid, ether, and others (Fig. 2). Among these compounds, 41 compounds of fatty hydrocarbon were found, which were much more than other categories. Terpenoid was another important category with 17 compounds identified. Only 1 organic acid and 2 ethers were found in the volatiles.

Table 1 exhibited the compound number of every volatile category. Not all volatile categories were emitted from these 6 tree peony cultivars. The volatile acids were only found

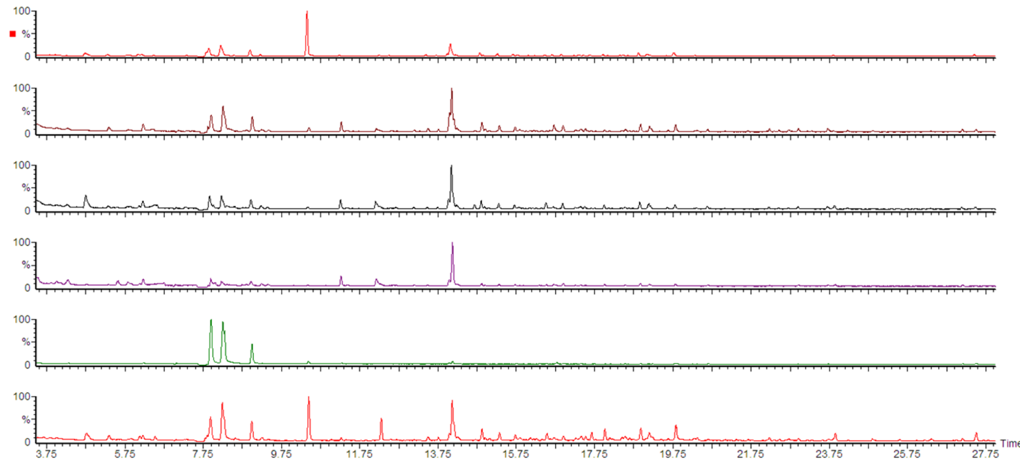

Fig. 1. The chromatographic profiles of floral scent emitted from 6 different tree peony cultivars (ZF, *Paeonia suffruticosa* 'Zhaofen'; LYH, *P. suffruticosa* 'Luoyanghong'; FDB, *P. ostii* 'Fengdanbai'; HN, *P.* × *lemonei* 'High noon'; R, *P.* × *lemonei* 'Renown'; and GYSH, *P. rockii* 'Gaoyuanshenghuo'). The visible difference in chromatographic profiles was found. Floral scent detected by GC/MS was collected for 20 min at a flow rate of 300 $mL \cdot min^{-1}$.

Table 1. The compound number of every volatile category emitted from 6 tree peony cultivars.

Cultivar[z]	Ester	Alcohol	Aldehyde	Fatty hydrocarbon	Benzenoid and derivative	Ketone	Acid	Terpene	Ether	Others
ZF	2	4	7	23	2	1	-[y]	7	1	1
LYH	3	2	8	22	1	1	-	3	-	5
FDB	3	4	6	19	1	2	-	5	-	4
HN	3	3	7	15	-	2	1	9	-	4
R	2	2	6	3	-	2	1	9	-	3
GYSH	1	5	4	15	2	2	-	7	1	3

[z]ZF, *Paeonia suffruticosa* 'Zhaofen'; LYH, *P. suffruticosa* 'Luoyanghong'; FDB, *P. ostii* 'Fengdanbai'; HN, *P.* × *lemonei* 'High noon'; R, *P.* × *lemonei* 'Renown'; GYSH, *P. rockii* 'Gaoyuanshenghuo'.
[y]Not detected.

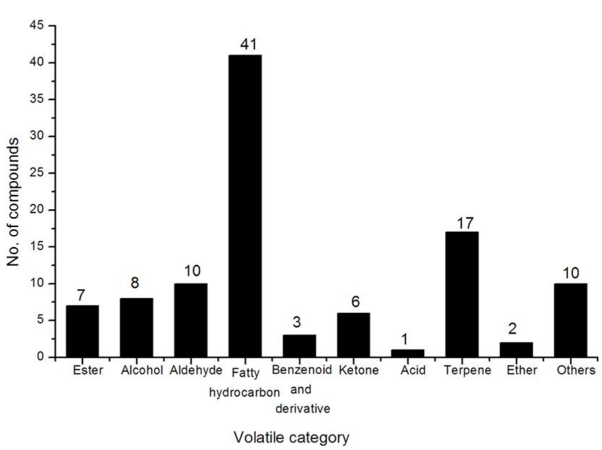

Fig. 2. The total compound number of every volatile category emitted from 6 tree peony cultivars. The number of different categories was widely different. Each point was average of at least three independent repeats.

to be emitted from 'HN' and 'R', on the contrary these two cultivars did not emit benzenoids. And ethers were also only found in the floral scent of the two cultivars, 'ZF' and 'GYSH'. It was found that except 'R' whose floral scent contained 28 compounds, the number of floral components emitted from other tree peony cultivars all exceeded 40. The flower of 'ZF' emitted floral scent with the most number (48) of components. And except 'R', more than 15 fatty hydrocarbons were found in the floral volatiles of other 5 tree peony cultivars, which were the most components. Whereas the numbers of esters, alcohols, benzenoids, ketones, acids, and ethers did not exceed 5 in all cultivars. The main volatile components were shown in Table 2, and visible difference was found. The volatile compounds of most content detected from 'ZH', 'LYH', 'FDB', 'HN', 'R', and 'GYSH' were α-pinene (42.45%), 2,3-dihydroxy propanal (30.41%), 3-methyl-1-butanol (23.67%), 2-ethyl-1-hexanol (19.76%), acetic acid 1-methylethyl ester (14.32%), and 5-ethyl-2,2,3-trimethyl heptane (23.61%) respectively.

The 6 peony cultivars emitted some shared compounds, such as aldehydes (hexanal, heptanal, octanal and so on) and terpenes (α-pinene and longifolene). And also some compounds were only emitted from peculiar cultivars, such as 3-methyl butanal, 4-methyl-1-hexene, and butylisopentyl ether, which were only found in the floral scent of 'ZF'. For 'LYH', 2,3-dihydroxy propanal, 2-hexenal, enolform pivaloylacetone, and 3-(acetylmethyl) beta-pinene were the

Table 2. The released amounts of main volatile components emitted from 6 tree peony cultivars.

Compound	Released amount (μg/h/flower)					
	ZF[z]	LYH	FDB	HN	R	GYSH
ESTER						
Acetic acid, 1-methylethyl ester	-[y]	-	-	12.40	31.00	-
Butanoic acid, 2-methyl-, methyl ester	-	-	-	8.05	-	-
Acetic acid, 2-methylpropyl ester	-	-	4.62	-	15.96	-
Acetoxyacetic acid, 4-pentadecyl ester	3.92	4.47	7.19	5.38	-	-
ALDEHYDE						
Butanal, 3-methyl-	14.05	-	-	-	-	-
Propanal, 2,3-dihydroxy-, (s)-	-	298.02	-	-	-	-
Hexanal, 3-methyl-	-	-	-	7.07	-	-
Hexanal	17.65	27.95	27.65	33.97	19.46	14.01
2-hexenal	-	5.23	-	-	-	-
Heptanal	5.74	3.36	4.21	6.50	2.05	6.25
Hexanal, 2-ethyl-	6.39	14.68	16.63	24.17	6.92	-
Octanal	2.47	2.32	3.39	3.36	1.80	3.79
Decanal	4.90	3.88	5.29	5.26	2.48	8.26
Nonanal	10.86	10.92	10.68	7.65	3.36	18.60
ALCOHOL						
1-butanol, 3-methyl-	39.76	-	132.98	-	-	-
1-decanol, 2-ethyl-	-	-	-	-	-	143.88
1-hexanol, 2-ethyl-	93.69	87.02	85.98	130.18	30.11	-
1-decanol	-	-	-	1.22	-	16.25
3-heptanol, 3,5-dimethyl-	5.17	3.04	4.27	2.63	-	5.11
KETONE						
2-propanone, 1-(1-methylethoxy)-	-	-	-	-	12.29	-
3-heptanone	-	-	-	6.26	-	-
Pivaloylacetone, enolform	-	7.27	-	-	-	-
2,4-hexanedione, 5,5-dimethyl-	-	-	27.17	31.41	12.83	-
Isophorone	7.48	1.78	-	-	-	24.02
6-tridecanone	-	-	3.24	-	-	-
ACID						
Propanoic acid, 2,2-dimethyl-	-	-	-	73.41	12.73	-
BENZENOID AND DERIVATIVE						
Benzaldehyde	1.28	-	-	-	-	-
Benzoic acid, 2-methylpropyl ester	3.96	2.02	2.02	-	-	5.80
Diethyl phthalate	-	-	-	-	-	7.70
TERPENE						
α-pinene	303.65	6.72	2.65	3.72	22.30	80.53
β-myrcene	-	-	-	3.97	1.25	-
D-limonene	-	-	17.91	21.13	2.63	13.08
β-ocimene	-	-	12.38	2.21	4.40	-
α-terpineol	-	-	-	-	-	7.51
cis-linaloloxide	-	-	-	11.15	3.06	-
4,7-methano-1H-indene, octahydro-	4.88	-	4.92	2.43	-	13.95
Linalool	-	-	-	58.05	26.12	-
Beta-pinene, 3-(acetylmethyl)-	-	3.70	-	-	-	-
Longifolene	10.44	3.95	5.24	2.49	2.54	23.48
Cedrene	1.38	1.01	3.18	1.50	-	-

Table 2. Continued.

Compound	Released amount (μg/h/flower)					
	ZF[z]	LYH	FDB	HN	R	GYSH
FATTY HYDROCARBON						
OLEFIN						
1-hexene, 4-methyl-	6.39	-	-	-	-	-
1-heptene	-	-	-	13.45	-	-
Heptane, 3-methylene-	-	14.94	-	27.95	-	-
1-octene	11.88	-	9.25	10.60	-	-
ALKANE						
Octane	-	-	6.63	19.11	-	-
Nonane, 3-methyl-	19.25	15.52	-	7.92	0.73	-
Octane, 2,6-dimethyl-	16.21	-	10.30	-	-	26.99
Heptane, 5-ethyl-2,2,3-trimethyl-	4.36	12.40	12.86	6.02	-	192.55
Decane, 2,3,4-trimethyl	10.52	8.55	7.84	8.79	-	23.81
Heptane, 2,2,4,6,6-pentamethyl-	4.15	7.32	4.83	-	-	-
Undecane	2.63	8.77	5.42	5.55	-	-
dodecane, 2,6,10-trimethyl-	7.42	-	-	3.76	-	1.17
Nonane	8.48	-	-	-	6.14	6.47
Decane, 2,2,6-trimethyl-	4.85	10.95	13.85	28.80	-	9.84
Undecane, 2,8-dimethyl	3.54	2.70	-	-	-	7.02
Decane, 3,3,8-trimethyl-	3.35	2.33	2.79	1.84	-	3.09
Dodecane	6.13	4.52	4.92	3.19	-	9.24
Tetradecane	3.89	3.45	4.96	4.34	2.17	-
ETHER						
1-methoxydecane	-	-	-	-	-	7.41
Ether,butylisopentyl	1.72	-	-	-	-	-
OTHERS						
Sulfurous acid, di(2-ethylhexyl)ester	-	10.92	12.17	8.20	-	22.43
1,3-propanediamine, N-methyl-	-	-	-	26.18	-	-

[z]ZF, *Paeonia suffruticosa* 'Zhaofen'; LYH, *P. suffruticosa* 'Luoyanghong'; FDB, *P. ostii* 'Fengdanbai'; HN, *P.* × *lemonei* 'High noon'; R, *P.* × *lemonei* 'Renown'; GYSH, *P. rockii* 'Gaoyuanshenghuo'.
[y]Not detected.

peculiar compounds. 5 compounds including 2-methyl butanoic acid methyl ester, 3-methyl hexanal, 3-heptanone, 1-heptene, and N-methyl-1,3-propanediamine were only identified in the floral scent of 'HN'. The volatiles only emitted from 'GYSH' were 2-ethyl-1-decanol, diethyl phthalate, α-terpineol, and 1-methoxydecane. And two ketones, 6-tridecanone and 1-(1-methylethoxy)-2-propanone were the peculiar compounds of 'FDB' and 'R' respectively.

Floral scent intensity was defined as the sum of the amount of the total volatiles (Wright et al., 2005). The floral scent intensity of 6 different tree peony cultivars were calculated (Fig. 3). Significant difference was found in the total released amounts of volatiles emitted from 6 cultivars. Among these 6 cultivars, 'GYSH' emitted the highest amounts of floral scent, nearly reaching 800 μg/h/flower, which was more than 3 times higher than that from 'R' (229.40 μg/h/flower). And the released amount of floral scent in 'ZF' was 714.79

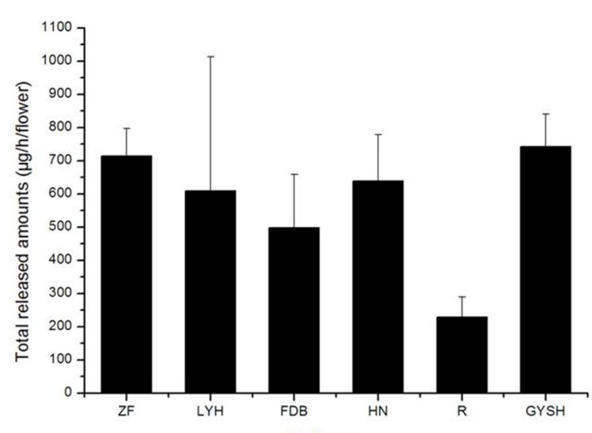

Fig. 3. The floral scent intensity of 6 tree peony cultivars (ZF, *Paeonia suffruticosa* 'Zhaofen'; LYH, *P. suffruticosa* 'Luoyanghong'; FDB, *P. ostii* 'Fengdanbai'; HN, *P.* × *lemonei* 'High noon'; R; *P.* × *lemonei* 'Renown'; and GYSH, *P. rockii* 'Gaoyuanshenghuo'). Each point was average of at least three independent repeats and bars represented standard errors.

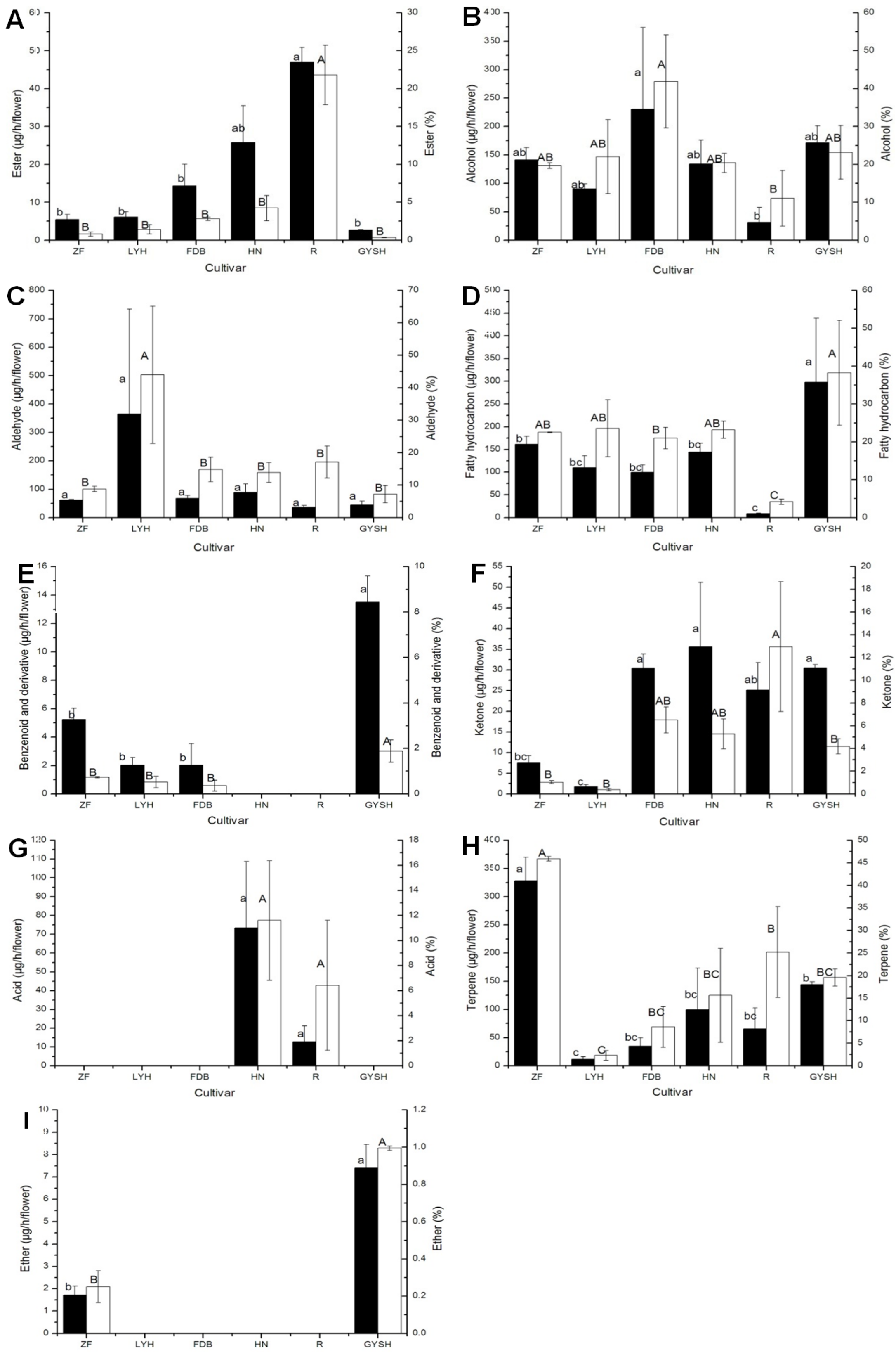

Fig. 4. The main volatile categories in 6 tree peony cultivars (ZF, *Paeonia suffruticosa* 'Zhaofen'; LYH, *P. suffruticosa* 'Luoyanghong'; FDB, *P. ostii* 'Fengdanbai'; HN, *P.* × *lemonei* 'High noon'; R, *P.* × *lemonei* 'Renown'; and GYSH, *P. rockii* 'Gaoyuanshenghuo'). The released amount of every volatile category (A, Ester; B, Alcohol; C, Aldehyde; D, Fatty hydrocarbon; E, Benzenoid and derivative; F, Ketone; G, Acid; H, Terpene; I, Ether) was significantly different among different cultivar. Each point was average of at least three independent repeats. Statistics significance (Duncan's new multiple range test) of differences among different cultivars was indicated by lowercase (released amount in μg/h/flower) and capital letter (relative amount in percentage) (P < 0.05). Bars represented standard errors.

μg/h/flower followed by 'HN' (639.36 μg/h/flower), 'LYH' (610.50 μg/h/flower), and 'FDB' (498.93 μg/h/flower).

Moreover, the released amount of volatile components exhibited significant difference (Fig. 4). For the compound categories emitted from all 6 tree peony cultivars, 'FDB' emitted the largest amount of alcohols (230.44 μg/h/flower), which exceeded 40% of its total released amounts of floral scent (498.93 μg/h/flower), and 3-methyl-1-butanol (132.98 μg/h/flower) and 2-ethyl-1-hexanol (85.98 μg/h/flower) were the main alcohols. Whereas the released amount of alcohols in the floral scent of 'R' only reached 31.31 μg/h/flower, the lowest in 6 cultivars. It was also found that 'R' emitted the lowest amount of fatty hydrocarbons and aldehydes. Especially for fatty hydrocarbons, the released amount from 'R' (9.04 μg/h/flower) was 30 times less than that from 'GYSH' (297.97 μg/h/flower). On the contrary, the released amount of esters from 'R' was 19 folds higher than that from 'GYSH'. Terpenoids were important components of many floral fragrances. The highest amount of terpenoids in this experiment was detected from 'ZF', the relative amount of which nearly accounted for 50%, and among the terpenoids α-pinene was the compound with the highest released amount (303.65 μg/h/flower). While 'LYH' emitted the lowest amount of terpenoids, which was 20 times less than that in 'ZF'. Moreover, the released amount of ketones was also determined the lowest among these 6 cultivars, which was only 1/20 of that in 'HN'. However, the released amount of aldehydes emitted from 'LYH' was highest, and nearly accounted for 45% of the total released amount.

The volatile acids, as a special class of compounds, were important components in the floral scent of 'HN', which almost arrived at 12% of total released amounts. Though the volatile acids were also found to be emitted from 'R', the released amount was 6 times lower than that from 'HN'. Among other 4 cultivars, 'GYSH' was found to emit the highest amounts of benzenoids and ethers.

Discussion

Floral scent, as a complex mixture of volatile organic compounds (VOCs) in plants, has been studied for many years. The survey of scientific publication on the subject of floral scent found that the earliest article was published in the middle of last century (Stashenko and Martinez, 2008). Over these years, multifunction of the floral scent has been discovered and reported (Dudareva and Pichersky, 2000; Dudareva et al., 2006). The components of many plants have also been detected (Knudsen, 2006; Stashenko and Martinez, 2008), and different volatile categories and released amounts were found. By 2006, the number of compounds identified had increased to 1719 (Knudsen, 2006). But in the plant kingdom, the floral scent of tree peony, an important landscape plant, at the state of nature was little known. In this study, floral volatiles of 6 tree peony cultivars in vivo were investigated, and totally 105 volatile compounds were identified, involving in ester, alcohol, aldehyde, fatty hydrocarbon, benzenoid and derivative, ketone, acid, terpene, ether, and nitrogen- and sulfur-containing compounds. Among these categories, a lot of fatty hydrocarbon compounds were identified, which were also found in previous studies on tree peony (Li, 2010; Liu, 1999; Zhou, 2008), and were thought to be essential components of floral scent emitted from vivo flowers (Shang et al., 2002).

The floral volatiles emitted from these 6 cultivars showed significant difference in quality and quantity. It was found that in the floral volatiles of 'R', not only the component number but also the total released amount was clearly less than other 5 cultivars, which was in agreement with the result of light fragrance through smelling. Moreover, except 'R', the number of fatty hydrocarbon compounds was all the largest in the floral scent emitted from other 5 cultivars. This might suggest that there was relatively large genetic distance between 'R' and other cultivars.

Among these 6 cultivars studied, 'ZF' was identified as the cultivar with the richest fragrance through smelling by persons, but its total released amount was not the highest. However in the components of floral scent, 'ZF' emitted significantly higher amount of terpenes than other cultivars, especially α-pinene, the released amount of which accounted for 42% of the total released amounts. So α-pinene could play a leading role in the floral scent of 'ZF' resulting in the rich fragrance. It was also found in previous studies that terpenes were important volatile components. For example, Raguso and Pichersky (1995) detected abundant linalool from *C. breweri*. Chen (2003) identified 3 monoterpenes (β-myrcene, limonene, and linalool) and several sesquiterpenes ((-)-(E)-β-caryophyllene, (+)-thujopsene, α-humulene, (E)-β-farnesene, (+)-β-chamigrene, and (-)-cuparene) from *Arabidopsis thaliana* flowers. (E)-β-ocimene was determined the prominent scent component of *Mirabilis jalapa* (Effmert, 2005). α-pinene, as an important monoterpene material of synthetic perfume, was also detected in other plants, such as *C. concinna* (Raguso and Pichersky, 1995), *P. lactiflora* (Huang et al., 2010) and *Hedychium coronarium* (Baez et al., 2011). But why 'ZF' emitted so large amount of α-pinene compared with other tree peony cultivars was unknown, and whether the synthesis pathway was activated need to be investigated in the following study.

Aldehydes were common volatiles emitted from plants. Hui (2001) detected large amount of aldehydes from barks of *Phellodendron amurese*. Li (2006) detected 4 abundant aldehydes from *Syringa oblata* flowers. And also lots of aldehyde compounds were detected from branches of *Gleditsia sinensis* and *Acer truncatum* (Zhang et al., 2007). Aldehydes were proved to have an antibacterial role. It was found that after attracting of herbivore on the leaves, aldehydes were emitted from damaged and systematic tissues to inhibit the invasion of microbe from the wound (Bate and Rothstein, 1998; Croft et al., 1993). Among these 6 cultivars, a large amount of aldehydes was detected from 'LYH' resulting in a little irritating odor. But the ecophysiological roles of these volatiles emitted from flowers have not been reported.

In sum, significant difference in the composition and released amount of floral scent was found among the tree peony cultivars studied. The results implied that the floral scent could be changed, even regulated through hybridization of different plant populations. The diversities of floral scent may result from differences in patterns of gene expression encoding enzymes responsible for the biosynthesis of volatile compounds and/or their precursors (Dudareva and Pichersky, 2000; Dudareva et al., 2003; Wright et al., 2005). But the emission mechanism of floral scent of tree peony was not reported. Our future work focuses on elucidating the biosynthesis pathways of floral scent, which will contribute to better understanding the diverse fragrances among different tree peony cultivars.

Literature Cited

Arimura, G., R. Ozawa, S. Kugimiya, J. Takabayashi, and J. Bohlmann. 2004. Herbivore-induced defense response in a model legume. Two-spotted spider mites induce emission of (E)-β-ocimene and transcript accumulation of (E)-β-ocimene synthase in *Lotus japonicus*. Plant Physiol. 135:1976-1983.

Baez, D., J.A. Pino, and D. Morales. 2011. Floral scent composition in *Hedychium coronarium* J. Koenig analyzed by SPME. J. Essential Oil Res. 23(3):64-67.

Bate, N.J. and S.J. Rothstein. 1998. C6-volatiles derived from the lipoxygenase pathway induce a subset of defense-related genes. Plant J. 16:561-569.

Chen, F., D. Tholl, J.C. D'Auria, A. Farooq, E. Pichersky, and J. Gershenzon. 2003. Biosynthesis and emission of terpenoid volatiles from Arabidopsis Flowers. Plant Cell 15:481-494.

Chen, Y.S. and S.H. Wu. 2005. Study on China's ancient tree peony culture. J. Beijing Forestry Univ. Social Sci. 4:18-23.

Croft, K.P.C., F. Jüttner, and A.J. Slusarenko. 1993. Volatile products of the lipoxygenase pathway evolved from *Phaseolus vulgaris* L. leaves inoculated with *Pseudomonas syringae* pv. *phaseolicola*. Plant Physiol. 101:13-24.

Dudareva, N., D. Martin, C.M. Kish, N. Kolosova, N. Gorenstein, J. Faldt, B. Miller, and J. Bohlmann. 2003. (E)-β-ocimene and myrcene synthase genes of floral scent biosynthesis in snapdragon: Function and expression of three terpene synthase genes of a new terpene synthase subfamily. Plant Cell 15:1227-1241.

Dudareva, N. and E. Pichersky. 2000. Biochemical and molecular genetic aspects of floral scents. Plant Physiol. 122:627-628.

Dudareva, N., F. Negre, D.A. Nagegowda, and I. Orlova. 2006. Plant volatiles: Recent advances and future perspectives. Critical Rev. Plant Sci. 25:417-440.

Effmert, U., J. Grobe, U.S.R. Röse, F. Ehrig, R. Kägi, and B. Piechulla. 2005. Volatile composition, emission pattern, and localization of floral scent emission in *Mirabilis jalapa* (Nyctaginaceae). Amer. J. Bot. 92:2-12.

Faegri, K. and van der Pijl L. 1979. The principles of pollination biology. 3rd ed. Pergamon, Oxford, UK.

Gershenzon, J. and R. Croteau. 1991. Terpenoids, p. 165-219. In: G.A. Rosenthal and M. Berenbaum (eds.). Herbivores: Their interaction with secondary plant metabolites. Academic Press, New York, USA.

Hu, Z.H., Y.B. Shen, Y.Q. Luo, F.Y. Shen, H.B. Gao, and R.F. Gao. 2008. Aldehyde volatiles emitted in succession from mechanically damaged leaves of poplar cuttings. J. Plant Biol. 51:269-275.

Huang, X., C. Wang, X.H. Wang, X.Z. Sun, and X.F. Guo. 2010. Preliminary study of aromatic components inherbaceous peonies of 'Yangfei Chuyu' and 'Dafugui'. Acta Hort. Sinica 37:817-822.

Hui, R.H., D.Y. Hou, T.C. Li, and J.L. Zhang. 2001. Analysis of volatile components in *Phellodendron chinense* Schneid. Chin. J. Analytical Chem. 29:361-364.

Jiang, Y.F., X.L. Chen, H. Lin, F. Wang, and F. Chen. 2011. Floral scent in wisteria: Chemical composition, emission pattern, and regulation. J. Amer. Soc. Hort. Sci. 136:307-314.

Jürgens, A., T. Witt, and G. Gottsberger. 2002. Flower scent composition in night-flowering *Silene* species (Caryophyllaceae). Biochem. System. Ecol. 30:383-397.

Kaori, S., T. Maeda, G. Arimura, R. Ozawa, T. Shimoda, and J. Takabayashi. 2002. Functions of plant infochemicals in tritrophics interactions between plants, herbivores and carnivorous natural enemies. Jpn. J. Appl. Entomol. Zool. 46:117-133.

Knudsen, J.T. 2006. Diversity and distribution of floral scent. Bot. Rev. 72:1-120.

Knudsen, J.T. and L. Tollsten. 1993. Trends in floral scent chemistry in pollination syndromes: Floral scent composition in moth-pollinated taxa. Bot. J. Linn. Soc. 113:263-284.

Knudsen, J.T., L.Tollsten, and G. Bergstrom. 1993. Floral scents - A checklist of volatile compounds isolated by headspace techniques. Phytochemistry 33:253-280.

Li, H.D., Y. Gao, and Y.J. Jin. 2004. The daily dymamic variances of the VOCS releasing from flowers of *Siberia kirilowii* (Regel) maxim. J. Inner Mongolia Agric. Univ. 25:54-59.

Li, M.R. 2010. Changes of aroma compounds and some related enzymes activity in tree peony petal during florescence and flower senescence. Henan Univ. Sci. Technol.

Li, Z.G., M.R. Lee, and D.L. Shen. 2006. Analysis of volatile compounds emitted from fresh *Syringa oblata* flowers in different florescence by headspace solid-phase microextraction -gas chromatography-mass spectrometry. Anal. Chim. Acta

576:43-49.
Liu, J.H., F.Y. Dong, C.G. Cheng, Y.J. Gu, and S.E. Li. 1999. Analysis of the essential oil chemical composition in peony flower. Shandong Chem. Ind. (3):35-36,18.
Pichersky, E. and J. Gershenzon. 2002. The formation and function of plant volatiles: Perfumes for pollinator attraction and defense. Curr. Opin. Plant Biol. 5:37-243.
Pichersky, E., R.A. Robert, E. Lewinsohn, and R. Croteau. 1994. Floral scent production in Clarkia (Onagraceae) 1. Localization and developmental modulation of monoterpene emission and linalool synthase activity. Plant Physiol. 106:1533-1540.
Ping, L., Y. Shen, and Y. Jin. 2001. Plant volatiles released in succession from artificially wounded ashleaf maple leaves. Aust. J. Plant Physiol. 28:513-517.
Raguso, R.A. and E. Pichersky. 1995. Floral volatiles from *Clarkia breweri* and *C. concinna* (Onagraceae): Recent evolution of floral scent and moth pollination. Plant Syst. Evol. 194: 55-67.
Raguso, R.A. and O. Pellmyr. 1998. Dynamic headspace analysis of floral volatiles: A comparison of methods. Oikos 81:238-254.
Shang, C.Q., Y.M. Hu, C.H. Deng, and K.J. Hu. 2002. Rapid determination of volatile constituents of *Michelia alba* flowers by gas chromatography-mass spectrometry with solid-phase microextraction. J. Chromatogr. 942:283-288.
Stashenko, E.E. and J.R. Martinez. 2008. Sampling flower scent for chromatographic analysis. J. Sep. Sci. 31:2022-2031.
Svensson, G.P., M.O. Hickman, S. Bartram, W. Boland, O. Pellmyr, R.A. Raguso. 2005. Chemistry and geographic variation of floral scent in *Yucca filamentosa* (Agavaceae). Am. J. Bot. 92:1624-1631.
Ton, J., M. D'Alessandro, V. Jourdie, G. Jakab, D. Karlen, M. Held, B.M. Mani, and T.C.J. Turlings. 2007. Priming by airborne signals boosts direct and indirect resistance in maize. Plant J. 49:16-26.
Wright, G.A., A. Lutmerding, N. Dudareva, and B.H. Smith. 2005. Intensity and the ratios of compounds in the scent of snapdragon flowers affect scent discrimination by honeybees (*Apis mellifera*). J. Comp. Physiol. A 191:105-114.
Wright, G.A., and B.H. Smith. 2004. Variation in complex olfactory stimuli and its influence on odour recognition. Proc. R. Soc. B 271:147-152.
Zhang, F.J., J.Q. Li, X.Y. Xu, X.D. Meng, and F.J. Chen. 2007. The volatiles of two greening tree species and the antimicrobial activity. Acta Hort. Sin. 34:973-978.
Zhang, H.L. 2011. The researches on variation of florescence, color and aromatic compounds in *Paeonia suffruticosa*. Shandong Agric. Univ.
Zhou, H.M., J.C. Qi, M.J. Dong, P. Li, and J.Q. Ma. 2008. Analysis of the volatile components in peony flowers by SPME-GC-MS. Chem. Anal. Meterage 17:21-23.