

Forensic value of pollen from ornamental indoor plants

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Abstract

Pollen is deposited almost everywhere and can be gathered and analysed. This work is part of a survey dedicated to indoor pollen from a forensic point of view. Ornamental plants were introduced into a private flat. Their influence on the pre-existing pollen assemblages was documented. Results show that ornamental plants can dramatically change the pollen spectra of indoor locations. The severity of this impact strongly varies with different plant taxa. These findings are important for forensic investigations, since such an ‘artificial’ pollen spectrum leaves an unusual trace and could subsequently relate a suspect to a crime scene.

Keywords: *pollen, ornamental plants, forensic palynology, domestic dwelling, pollen spectrum*

Pollen is the source and carrier for the male gametes of seed plants. Through wind, animals or water, pollen is transferred from the male to the female reproduction organ to enable fertilisation and sexual reproduction. However, not all pollen grains reach their destination. Therefore, pollen can be found almost everywhere, e.g. on soil, leaves, clothes, animals, cars, shoes and indoor locations. Numerous factors summarised under the term ‘palynological taphonomy’ (Wiltshire 2006) influence the whereabouts of pollen. This leads to distinct pollen accumulation at different places. Forensic palynologists use such pollen spectra (Klaus 1987) to answer questions concerning crimes (Bryant & Mildenhall 1998; Mildenhall 2004; Mildenhall et al. 2006). In this study, the term ‘pollen spectrum’ (or pollen spectra) refers to the totality of the pollen types as well as their percentage share in a sample.

This study is part of a survey dedicated to pollen in domestic dwellings and its use in forensic cases. A previous publication reports on the ‘natural’ pollen content of a private flat, which was monitored over two seasons (Preusche & Weber 2014). Results showed a strong influence of seasonal pollen on the indoor spectra. The aim of the present study was to

document how ornamental plants will change and influence the ‘natural’ pollen content of this flat. Ornamental plants were introduced and the abundance of their pollen was documented. An investigation over such a long time (almost one year) has never been done before. This allowed observing the seasonal impact, which is also a novelty in this research field.

This study was designed to document a ‘real-life’ situation and to answer the following questions: (1) Are the pollen spectra of the various rooms modified by indoor plants? (2) How strong is the individual impact of different plants and which pollen types are most dominant? (3) How extraordinary are the resulting pollen spectra and can they be considered as a valuable trace in legal cases?

Material and methods

Locality and sampling

Two rooms (living room and kitchen) of a private flat (fourth level, two occupants, no pets; Figure 1) in Vienna, Austria, were sampled from 4 October 2012 to 8 September 2013, for pollen deposited on the floor using duster sheets (‘Swiffer Staubmagnet’).

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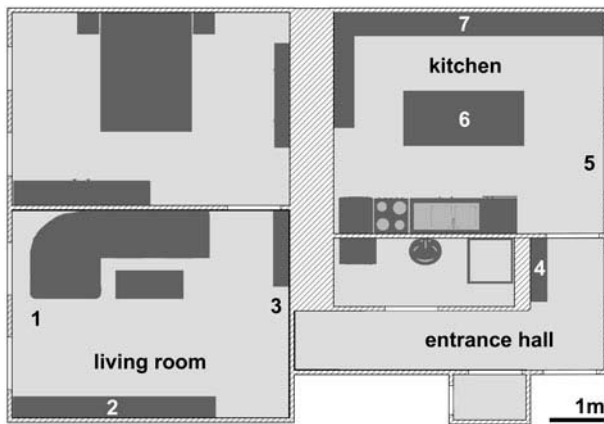


Figure 1. Layout of the flat. Numbers indicate the placement of the various indoor plants (Table I).

During this time, flowering pot plants and cut flowers (further referred to as ‘indoor plants’) were present in the flat (Figure 1, Table I). *Euphorbia leuconeura* Boiss., *Hibiscus* sp. (French et al. 2005), *Lavandula stoechas* L. (Herrera 1997) and *Spathiphyllum* sp. (Gibernau 2003) were placed in the living room. *Alstroemeria* sp. (Aizen 2001; Madjidian et al. 2008; Suárez et al. 2009; Botto-Mahan et al. 2011), *Callistemon* sp. (Tope et al. 2012), *Clivia miniata* (Lindl.) Bosse (Kiepiel & Johnson 2014), *Lilium* sp. (Yokota & Yahara 2012) were situated in the kitchen. Caryophyllaceae (Jürgens et al. 2003) and *Fuchsia* sp. (Traveset et al. 1998) were present in both rooms. *Ilex* sp. (Tsang & Corlett 2005) was placed in the entrance hall. With the exception of *Euphorbia leuconeura*, all these plants are entomophilous. The plants had to meet the requirement that their pollen grains are easily identifiable and were rare or not present in the pre-existing pollen assemblages. Pollen samples were taken for comparison.

The living room had laminate flooring while the kitchen had stone floor tiles. Previous works showed that duster sheets are great for picking up pollen from most indoor surfaces, supposedly due to electrostatic forces. To simulate real life conditions, the flat was used in a ‘normal’ way. This included opening of windows and doors at irregular intervals, the use of electric fans and vacuum cleaning (once a week).

Some things have to be considered when taking indoor samples: Usually the pollen concentration indoors is lower than outdoors (Hugg & Rantio-Lehtimäki 2007). Additionally, indoor areas are spatially more limited. Therefore, it can occur that a sampling site may not deliver enough pollen grains for a legitimate analysis, especially when the sampled area is too small. To bypass this problem, pollen was gathered by wiping the whole floor of

one room with one pristine duster sheet. The floor was sampled, because it is the place, where most pollen grains can be found at an indoor location (Enomoto et al. 2004). An advantage of the limited space is that the whole area can be represented in one sample. Outdoors, e.g. in a forest, this is often impossible and, therefore, methods like the ‘pinch-method’ (Bryant et al. 1990) are a better approach. Altogether, 66 samples were taken (Tables II, III).

Pollen isolation and identification

The duster sheets as well as pristine sheets that served as a reference were washed with distilled (pollen sterile) water mixed with a drop of Tween 20. By centrifugation (3000 rpm) of the washing water, solid and liquid phases were separated. The solid remains were processed using a modified acetolysis technique (Erdtman 1943; Hesse et al. 2009) as has been used in a previous study (Preusche & Weber 2014): rinse with acetic acid (100%); decant acetic acid and add acetolysis mixture: nine parts acetic acid anhydride (99%) and one part sulphuric acid (96%); heat in a water bath (100 °C) for approximately eight minutes; rinse with acetic acid (100%); rinse with distilled water (several times); rinse with ethanol (99.8%) to dry the sample; add glycerine to the sample and fill it into vials. During sample processing, the laboratory was monitored for pollen contamination.

Approximately 20 µl of the glycerine/pollen mixture were put on a microscope slide, covered with a cover-glass and observed with a light microscope (Olympus BX 53F) at magnifications up to 600×. The advantage of glycerine compared to fixed embedding is that with applying a slight pressure on the cover-glass, a pollen grain can be turned from, e.g. polar to equatorial view for better identification. To preserve the microscopic slides for future controls, the cover-glass was fixed after counting. The pollen grains were identified and assigned to different pollen types with the help of the literature (Reille 1992; Beug 2004; Hesse et al. 2009) and the pollen database PalDat (Buchner & Weber 2000). Approximately 300 pollen grains were counted per sample excluding unidentifiable palynomorphs and saccate pollen. The later were excluded, because huge amounts of saccate pollen were floating on the surface of the decanted water and were, therefore, lost during sample processing. Occasionally, more grains were counted to verify the results when one pollen type was extremely dominant, but they were not excluded from analysis since these pollen types were always the most interesting ones.

Pollen grains from the indoor plants were photographed at a magnification of 600× (Figure 2). The fraction of each indoor pollen type, as well as the sum of all other pollen types ('Others') was calculated (Tables II, III). The abundance of the four most common indoor pollen types in the living room and the kitchen was graphically illustrated (Figures 3, 4).

Results

Before the indoor plants were introduced into the flat, wind-pollinated taxa like Urticaceae, Poaceae, *Betula*, *Ambrosia*, *Quercus*, *Amaranthaceae*, *Populus* and others were most common in the living room and kitchen (Preusche & Weber 2014). Caryophyllaceae, *Euphorbia*, *Fuchsia*, *Hibiscus*, *Lavandula* and *Spathiphyllum* were introduced into the living room at different dates (Table I). The pollen content changed dramatically in November 2012 after *Spathiphyllum* was placed in the flat (27 October 2012). This pollen type became the most abundant one until 11 April 2013. *Alstroemeria* and *Clivia* were frequently found throughout this period, though

always in lower numbers. From May 2013 onwards, pollen from wind-pollinated taxa was most common, with some occurrences of pollen from Caryophyllaceae, *Clivia*, *Ilex*, *Lamiaceae* and *Liliaceae*. *Callistemon* was present in most samples (Table II).

Alstroemeria, *Callistemon*, Caryophyllaceae, *Clivia*, *Fuchsia* and *Lilium* were introduced into the kitchen at different dates (Table I). From November 2012 to April 2013, *Alstroemeria*, *Clivia* and *Spathiphyllum* were the most common pollen types. Additionally, wind-pollinated taxa also accounted for a big share. From May to September 2013, *Callistemon* became the most dominant pollen type accompanied by *Liliaceae* and wind-pollinated taxa (Table III).

Discussion

Most studies concerning indoor pollen focus on pollen from an allergological point of view (Enomoto et al. 2004; Hugg & Rantio-Lehtimäki 2007). Many of them report that pollen can be found at indoor locations and that wind-pollinated taxa are predominant (Yankova 1991; Tormo-Molina et al. 2009).

Table I. List of the plants present in the flat.

Plant taxon	Introduced	Removed	Number of days ¹	Cut flowers (c) pot plant (p)	Number of flowers ²	Pollination type (Pollinators)	Placement (see Figure 1)
<i>Alstroemeria</i> sp. (Alstroemeriaceae)	30.10.2012	01.04.2013	117	c	7–12	Entomophilous (Hymenoptera, Diptera)	6
<i>Callistemon</i> sp. (Myrtaceae)	29.04.2013	08.08.2013	102	p	6–10(i)	Entomophilous (Hymenoptera, Diptera)	5
Caryophyllaceae	02.07.2013	12.07.2013	11	c	10	Entomophilous	6
	08.08.2013	23.08.2013	16	c	10	(Lepidoptera)	2
<i>Clivia miniata</i> (Amaryllidaceae)	12.11.2012	17.04.2013	132	p	0–14	Entomophilous (Lepidoptera)	5
<i>Euphorbia leuconeura</i> (Euphorbiaceae)	11.10.2012	09.09.2013	334	p	9–19	Autogamous	3
<i>Fuchsia</i> sp. (Onagraceae)	29.04.2013	19.06.2013	52	p	0–41	Ornithophilous	7
	24.06.2013	05.07.2013	13	p	0–22		2
<i>Hibiscus</i> sp. (Malvaceae)	29.04.2013	19.06.2013	52	p	0–18	Ornithophilous	1
							2
<i>Ilex</i> sp. (Aquifoliaceae)	29.04.2013	12.07.2013	75	p	0–1	Entomophilous	4
<i>Lavandula stoechas</i> (Lamiaceae)	29.04.2013	19.06.2013	52	p	~42(i)	Entomophilous	2
<i>Lilium</i> sp. (Liliaceae)	31.07.2013	13.08.2013	14	c	24	Entomophilous	6
	26.08.2013	03.09.2013	9	c	10		6
<i>Spathiphyllum</i> sp. (Araceae)	27.10.2012	24.04.2013	180	p	5–7(i)	Entomophilous	1
							2

¹*Alstroemeria* cut flowers were frequently removed when they withered and replaced with new ones, resulting in the absence of the flowers on some days (10–13.11.2012; 08–13.12.2012; 28.12.2012–03.01.2013; 15–24.01.2013; 09–18.02.2013). The same applies for *Clivia*, which was replaced when all flowers withered (absent from 01.01.2013–27.01.2013).

²Number of flowers changed by withering and new blossoming, lowest number and highest number of observed flowers are given. In some cases, all flowers withered or dropped, resulting in no flowers left (0). For *Callistemon*, *Lavandula* and *Spathiphyllum*, the flower-heads (inflorescences) are given (i).

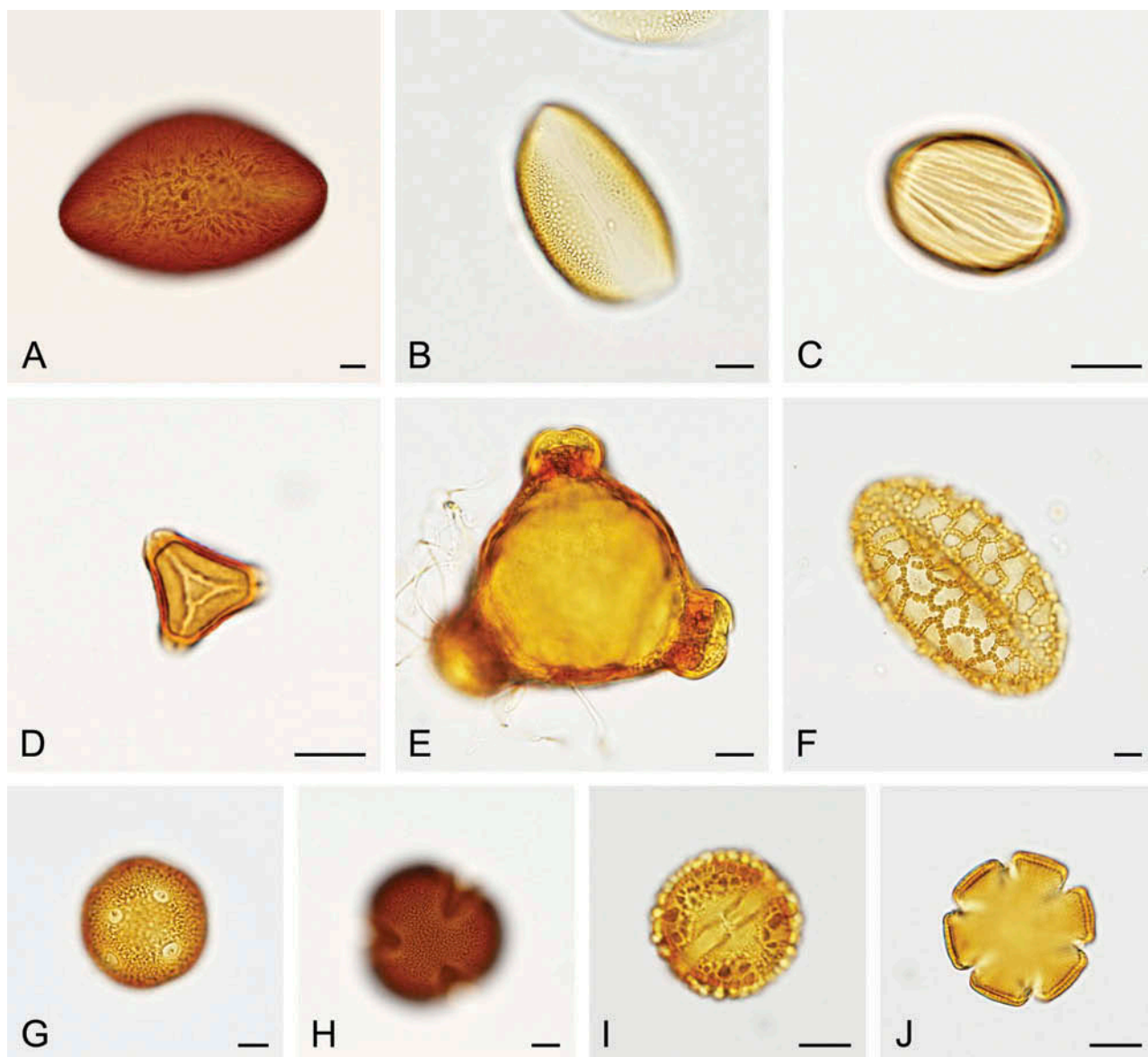


Figure 2. Pollen grains recorded in the flat. **A.** *Alstroemeria*. **B.** *Clivia*. **C.** *Spathiphyllum*. **D.** *Callistemon*. **E.** *Fuchsia*. **F.** *Lilium*. **G.** Caryophyllaceae. **H.** *Euphorbia leuconeura*. **I.** *Ilex*. **J.** *Lavandula stoechas*. All acetolysed. Scale bars – 10 μ m.

Furthermore, a relation between indoor pollen and the flowering period of the corresponding outdoor plants was documented (Caramiello et al. 1990; Emberlin et al. 1990). The same was observed in this study before the indoor plants were introduced (Preusche & Weber 2014). Regarding the seasonal pattern, the findings of 2013 correlate with those of 2011 and 2012. Studies on indoor pollen from a forensic point of view are quite rare and only some of them focus on pollen from indoor plants. Morgan et al. (2008, 2014) report that pollen from cut flowers can be found in a flat throughout the time when the flowers are present. The authors further report that these pollen types were still detectable weeks after the associated plants were removed. In the

present study, the effect of a greater variety of plants was investigated over a longer period of time.

Dominant pollen types

Spathiphyllum. — Immediately after placement of *Spathiphyllum* (Araceae) in late October 2012, a huge amount of this pollen type was documented in the living room, but not in the kitchen (Figures 3, 4). Approximately one month later, pollen from *Spathiphyllum* became more common in the kitchen as well (Table III). After removal of the plants, this pollen type was rarely found in the kitchen, but was frequent in the living room, though always below 6%. The reason for this rapid decrease

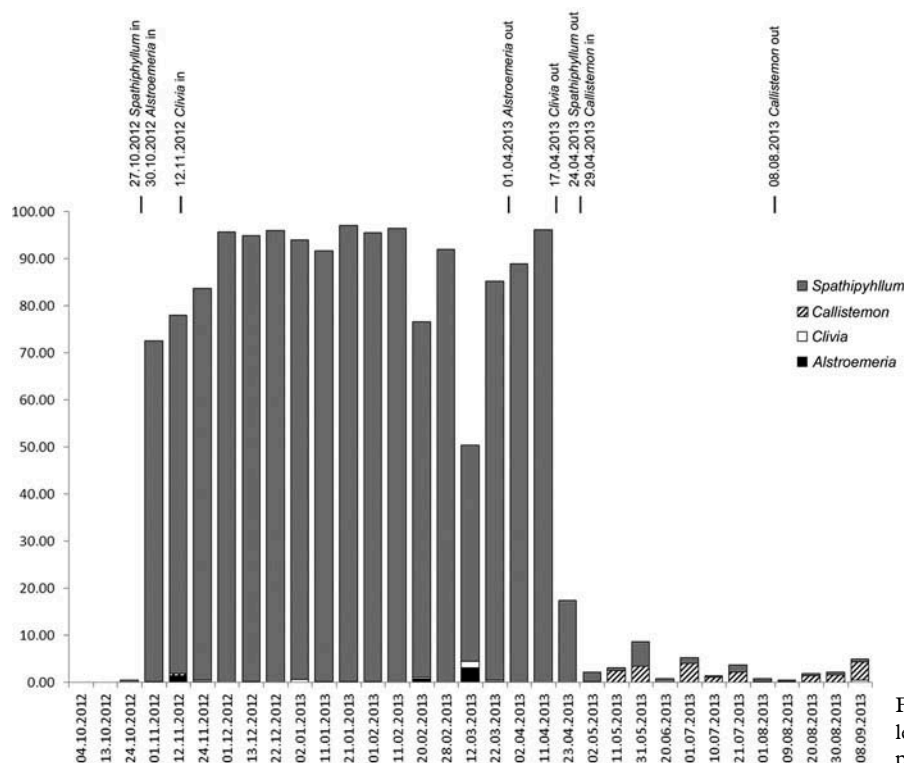


Figure 3. Graph bar of the dominant pollen types in the living room: x-axis = sampling dates; y-axis = percentages.

in the amount of *Spathiphyllum* pollen is most certainly based on cleaning and sampling activities combined with the intrusion of outdoor pollen. Cleaning generally reduces the amount of pollen in a flat. The combination of already lower amounts of *Spathiphyllum* and the infiltration of outdoor pollen caused the rapid drop in the percentages of *Spathiphyllum*. Interestingly, *Spathiphyllum* pollen grains were sporadically found before October 2012 (Preusche & Weber 2014). Most likely, they originated from a *Spathiphyllum* pot plant that was present in the kitchen since April 2010. It was documented, that this plant never flowered from 2011 to 2013. Therefore, it is assumed that these pollen grains remained in the flat (on the floor, on furniture or on the leaves of the plant) for more than two years.

For several reasons, these findings are of forensic importance: If pollen from pot plants can dominate the pollen spectrum of a room, it is to be expected that this pollen will adhere to persons entering the room (Jantunen & Saarinen 2011). Since *Spathiphyllum* is a tropical plant, it is unlikely this pollen type would occur in surface soil samples (or any other outdoor sample) outside the Tropics. Thus, this pollen can function as an unusual marker that could at least give circumstantial evidence matching a suspect to a crime (Bryant et al. 1990; Mildenhall 2006; Mildenhall et al. 2006) or in particular to an

indoor crime scene. Furthermore, if *Spathiphyllum* pollen can persist indoors for months, the probability increases that such a trace exists at an indoor location, as does the probability that it is picked up by a perpetrator (Morgan et al. 2014). However, there are limitations to the forensic value of *Spathiphyllum*, because it is a popular indoor plant and its pollen might be present in quite a few flats.

Alstroemeria and *Clivia*. — *Alstroemeria* (Alstroemeriaceae) and *Clivia* (Amaryllidaceae) had a big influence on the pollen spectra of the kitchen right after they were introduced (Table III). In the living room, these pollen types were only found in small amounts (Table II). While *Spathiphyllum* was stable at a high level, the values of *Alstroemeria* and *Clivia* varied strongly. One reason for these fluctuations is that both plants shed their pollen at the same time and at the same place. Therefore, if one plant shed its abundant pollen, the other was correspondingly less dominant, i.e. its percentages fell (Figures 3, 4). Additionally, both plants were sometimes replaced with new individuals when the old ones stopped flowering. Some of the highest values for both pollen types were recorded shortly after the plants were removed, because discarding the plants shook additional pollen to the floor. When such disturbances affect two plants at different times, it could also intensify alternating peaks (Figures 3, 4).

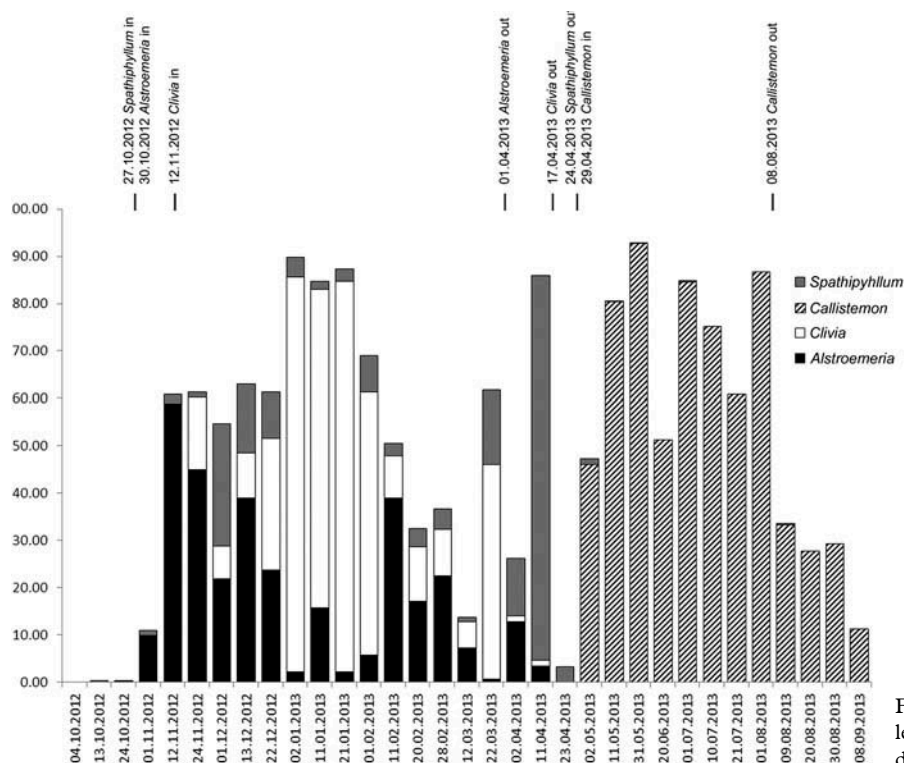


Figure 4. Graph bar of the dominant pollen types in the kitchen: x-axis = sampling dates; y-axis = percentages.

The forensic value of *Alstroemeria* and *Clivia* pollen is similar to that of *Spathiphyllum* since they are also entomophilous and in Austria only common as ornamental plants. It must be pointed out that some *Clivia*-type pollen grains were found before the plant was present in the kitchen. In six samples, a single grain each was documented, in one sample three grains were found (all seven samples were counted to 300). These grains could have originated from a *Haemanthus* sp. (Amaryllidaceae) pot plant that stood some floors below in the public staircase in the building. Some stamens of this plant were collected for comparison. The pollen grains were not distinguishable from *Clivia* pollen grains with a light microscope. However, it cannot be proven that the grains in question originated from the *Haemanthus* sp. plant. Another source might be possible.

Furthermore, a single *Alstroemeria* pollen grain was found six days before the plant was introduced into the flat (24 October 2012, Table III). Twelve days before that (12 October 2012), *Alstroemeria* flowers were processed in the laboratory (approximately 5 km from the flat) to get comparative samples. The transport of pollen through clothing has been reported before (Zavada et al. 2007; Takahashi et al. 2008; Jantunen & Saarinen 2011). It is imaginable, that some *Alstroemeria* pollen grains got

picked up in the laboratory by shoes or clothing and were transported to the flat. However, any other (secondary or tertiary) vector may have led to the presence of this pollen type at that date. Additionally, *Alstroemeria* pollen was found in the living room before this study started: on the 8 and 18 October 2011. In both cases, it was a single grain in a count to approximately 300. In those cases, no *Alstroemeria* flowers were present in the flat and the origin is unclear. Therefore, the finding of a single pollen grain, no matter how uncommon in the geographical region in question, is of meagre forensic value. It can always have originated from an unknown source.

Callistemon. — On 29 April 2013, a *Callistemon* (Myrtaceae) pot plant was placed in the kitchen. After that, the values for *Callistemon* increased dramatically in this room (Figure 4). These high values were recorded during spring and summer. *Callistemon* pollen outnumbered seasonal pollen entering from outdoors. It is assumed that *Callistemon* shed even more pollen than *Spathiphyllum*, because *Spathiphyllum* (high values in winter/spring) lacked competition for many months. Thus, *Callistemon* can also cause unexpected pollen spectra.

Table II. Indoor pollen types, percentages (living room).

Sampling date	<i>Astroemeria</i>	<i>Callistemon</i>	Caryophyllaceae*	<i>Clivia</i>	Euphorbiaceae*	<i>Fuchsia</i>	<i>Ilex</i>	Lamiaceae*	Liliaceae	<i>Spathiphyllum</i> *	Others	Pollen grains counted
04.10.2012	-	-	-	-	-	-	-	-	+	-	100	298
13.10.2012	-	-	-	-	-	-	-	-	-	-	100	307
24.10.2012	-	-	-	-	+	-	-	+	+	1	98	303
01.11.2012	-	-	-	+	-	-	-	-	-	72	27	337
12.11.2012	2	+	-	-	-	-	-	-	-	76	22	305
24.11.2012	+	-	-	+	3	-	-	-	-	83	13	309
01.12.2012	+	-	-	-	-	-	-	-	-	96	4	2336
13.12.2012	+	-	-	-	-	-	-	-	-	95	5	317
22.12.2012	-	-	-	+	-	-	-	-	+	96	4	1875
02.01.2013	+	-	-	1	-	-	-	-	-	93	6	964
11.01.2013	-	-	-	+	-	-	-	-	1	91	8	328
21.01.2013	-	-	-	+	-	-	-	-	-	97	3	310
01.02.2013	-	-	-	+	-	-	-	-	-	95	4	315
11.02.2013	-	-	-	-	-	-	-	-	-	96	4	311
20.02.2013	1	-	-	+	-	-	-	-	-	75	23	318
28.02.2013	-	-	-	-	-	-	-	-	-	92	8	326
12.03.2013	3	-	-	1	-	-	-	-	+	46	49	303
22.03.2013	+	-	-	+	-	-	-	-	-	85	15	307
02.04.2013	-	-	-	-	+	-	-	-	-	89	11	674
11.04.2013	+	-	-	+	+	-	-	-	-	96	4	2499
23.04.2013	-	-	-	-	-	-	-	-	-	18	82	308
02.05.2013	-	+	-	-	-	-	-	-	-	2	98	308
11.05.2013	-	3	-	-	-	-	-	2	-	1	95	309
31.05.2013	-	4	-	-	-	-	1	2	-	5	89	308
20.06.2013	-	-	-	-	-	-	-	1	-	1	98	308
01.07.2013	-	4	-	-	-	-	-	-	-	1	95	315
10.07.2013	-	1	-	-	-	-	-	1	-	+	98	308
21.07.2013	-	2	-	-	-	-	1	-	-	2	95	306
01.08.2013	-	+	-	-	-	-	-	-	+	1	99	308
09.08.2013	-	+	-	-	-	-	-	-	2	+	97	310
20.08.2013	-	2	-	-	-	-	-	-	+	+	97	305
30.08.2013	-	2	1	-	-	-	+	-	2	1	94	302
08.09.2013	-	4	4	1	-	-	+	-	1	1	90	310

Percentages rounded to integer.

- Pollen type was not documented on this date.

+ Pollen type was present, but below 0.5%.

* Placed in the living room.

Table III. Indoor pollen types, percentages (kitchen).

Sampling date	<i>Alstroemeria</i> *	<i>Callistemon</i> *	Caryophyllaceae*	<i>Clivia</i> *	Euphorbiaceae	<i>Fuchsia</i> *	<i>Ilex</i>	Lamiaceae	Liliaceae*	<i>Spathiphyllum</i>	Others	Pollen grains counted
04.10.2012	-	-	-	-	-	-	-	-	+	-	100	292
13.10.2012	-	-	+	-	-	-	-	-	1	+	98	307
24.10.2012	+	-	-	-	2	-	-	-	-	-	98	302
01.11.2012	10	-	-	-	+	-	-	-	+	1	88	302
12.11.2012	59	-	-	-	-	-	-	-	-	2	39	306
24.11.2012	45	-	-	15	-	-	-	-	-	1	39	307
01.12.2012	22	-	+	7	-	-	-	-	1	26	44	302
13.12.2012	39	-	-	9	-	-	-	-	-	15	37	295
22.12.2012	24	-	-	28	-	-	-	-	-	10	38	308
02.01.2013	2	-	-	83	+	-	-	-	-	4	10	312
11.01.2013	16	-	-	67	-	-	-	-	-	2	15	312
21.01.2013	2	-	-	82	-	-	-	-	-	3	13	364
01.02.2013	6	-	-	55	-	-	-	-	-	8	31	312
11.02.2013	39	-	-	9	-	-	-	-	-	3	50	303
20.02.2013	17	-	-	12	1	-	-	-	1	4	65	304
28.02.2013	23	-	-	10	+	-	-	-	-	4	63	306
12.03.2013	7	-	-	6	-	-	-	-	-	+	86	593
22.03.2013	1	-	-	45	-	-	-	-	+	16	38	308
02.04.2013	13	-	-	1	-	-	-	1	-	12	73	306
11.04.2013	3	-	+	1	-	-	-	-	-	81	14	320
23.04.2013	-	-	-	-	-	-	-	-	-	3	97	310
02.05.2013	-	46	-	-	-	-	-	-	-	1	53	311
11.05.2013	-	80	-	-	-	-	-	-	-	+	19	1493
31.05.2013	-	93	-	-	-	-	+	-	-	+	7	1618
20.06.2013	-	51	-	-	-	-	-	-	-	-	49	331
01.07.2013	-	85	-	-	-	-	-	-	-	+	15	1064
10.07.2013	-	75	-	+	-	+	+	-	-	-	24	932
21.07.2013	-	61	-	-	-	-	-	-	-	-	39	312
01.08.2013	-	87	+	+	-	-	-	+	4	-	9	2414
09.08.2013	-	33	-	-	-	-	-	-	45	+	22	307
20.08.2013	-	28	-	-	-	-	+	-	2	-	70	310
30.08.2013	-	29	-	-	-	-	-	-	3	-	68	341
08.09.2013	-	11	-	-	-	-	-	-	+	-	88	309

Percentages rounded to integer.

- Pollen type was not documented on this date.

+ Pollen type was present, but below 0.5%.

* Placed in the kitchen.

Liliaceae. — Liliaceae pollen was found in both rooms throughout the time, the plant was present in the kitchen. With 45% on 9 August 2013, a very high abundance was documented in the kitchen. It can be assumed that *Lilium* can also cause dramatic changes to pre-existing pollen spectra.

Rare pollen types

Other pollen types were rarely found throughout this study (none of them surpassed 5%) and are further referred to as 'rare pollen types' (even if they might be more common in general). The highest value for Caryophyllaceae was documented after it was removed from the living room (4%; 8 September 2013), but it was not found when it was present in the kitchen a month before that.

Lamiaceae pollen was rarely found throughout the two years. Nevertheless, from May to September 2013, low abundances (< 3%) were documented in the living room as well as occasional findings in the kitchen. It is assumed that this was caused by the *Lavandula stoechas* pot plant in the living room. However, Lamiaceae pollen was documented occasionally before the plant was introduced. Since Lamiaceae plants are common in Austria, these pollen grains could have originated from outdoor plants, too.

Some grains of *Ilex* (Aquifoliaceae) were occasionally recorded in both rooms after the plant was placed in the entrance hall. Additional samples from the entrance hall showed that its highest abundance could be found there (4%; 2 May 2013).

Pollen from *Euphorbia leuconeura* (Euphorbiaceae) was occasionally documented in both rooms. *Fuchsia* (Onagraceae) pollen was found in one kitchen sample only (10 July 2013).

These 'rare pollen types' only had a small impact on the pollen spectra of the flat. However, these traces could also adhere to a person entering the room and might be interesting forensically because their pollen is rare. Therefore, their forensic potential should not be underestimated, but attention must be paid to the natural abundance of such plants.

Pollen types not found

Pollen from *Hibiscus* sp. (Malvaceae) was not documented. Comparative samples from the anthers showed that the pollen production of this plant was very low (only some grains could be found in the comparative samples). Most indoor plants shed enough pollen to be easily recognised in the dust

samples. The abundance was particularly high when the associated plant was present or shortly after its removal. Lower abundances were recognisable for a much longer time. Furthermore, when plants were relocated or removed, disturbances caused additional distribution of pollen. *Spathiphyllum*, *Clivia*, *Alstroemeria*, *Callistemon* and *Lilium* shed so many pollen grains that they dominated the pollen spectra. However, not all plants shed that much pollen. There are numerous reasons why some pollen types were more or less abundant. One reason is that some plants produce more pollen than others (Bryant & Mildenhall 1998). The amount of produced pollen depends on the pollination type and growth form of the plant (Mondal & Mandal 1998; Milne et al. 2004) and is often typical for a genus or species (Denisow 2008), and may even vary between cultivars (Denisow et al. 2013). Furthermore, it was reported, that (micro-)climatic conditions can alter pollen production (Herlihy & Delph 2009; Jochner et al. 2011; Aguilera & Ruiz Valenzuela 2012). The same might happen indoors. Therefore, it is nearly impossible to project the amount of pollen produced by an indoor plant. To estimate the amount of pollen, the number of pollen grains per anther as well as stamens per flower, flowers per inflorescence and the numbers of inflorescences per plant individual must be considered (Reddi & Reddi 1986; Tormo-Molina et al. 1996; Mondal & Mandal 1998; Piotrowska 2008).

It is suggested, that most pollen grains simply fell down while the flowers withered, which would lead to a distribution of pollen next to the associated plant. Wind entering through windows or doors would possibly cause a distribution in a broader area. Therefore, it might not have been the most important factor, because all pollen types were more abundant in the room, in which the plant actually stood, and less abundant in the other room (Tables II, III). In principal, all introduced plants caused such a distribution. This imbalance remained intact as long as the associated plant was still present, but became gradually indistinct after time. A decline in the amount of pollen over time as well as spatial trends was also reported by Morgan et al. (2014). Tormo-Molina et al. (2009) reported no differences between four rooms in one building. The most important difference between these studies is that the present study and Morgan et al. (2014) report spatial trends for pollen from zoophilous plants, while Tormo-Molina et al. (2009) dealt with pollen from anemophilous plants. In the majority of cases, pollen from zoophilous plants is stickier than pollen from anemophilous plants (Pacini &

Hesse 2005). This stickiness is a function of the amount, consistence and distribution of pollenkitt among the pollen grain as well as the structure of the exine (Hesse 1978, 1979a, 1979b, 1979c, 1981; Lin et al. 2013). Therefore, zoophilous pollen will more effectively adhere to the floor and its relocation is less likely.

Conclusion

The present study shows that pollen from indoor plants can influence the pre-existing pollen spectra in a domestic dwelling. Exotic indoor plants can cause pollen spectra that are very rare, especially when different plant types are mixed. This is of importance for forensic investigations as such an unusual trace could adhere to a perpetrator and might help to match a suspect to a crime scene. The rarity of such a trace has to be considered carefully, as it strongly depends on multiple factors such as the abundance of the plant (species) in the natural surroundings, the popularity as an ornamental plant and the amount of pollen shed by the plant. On the one hand, plants that produce/shed a huge amount of pollen will more likely leave a trace that could adhere to a perpetrator. On the other hand, if pollen from a plant that sheds only a few grains is found in the course of a forensic investigation, its value is particularly high. A combination of more than one rare pollen type in a forensic sample is of course a best case scenario. Despite that, care must be taken when interpreting such minute occurrences, because single grains can travel via unexpected vectors and might show up anywhere. Therefore, not only the occurrence of a special pollen type is important, but also its abundance.

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