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The grass pollen season 2014 in Vienna: A pilot study combining phenology, aerobiology and symptom data

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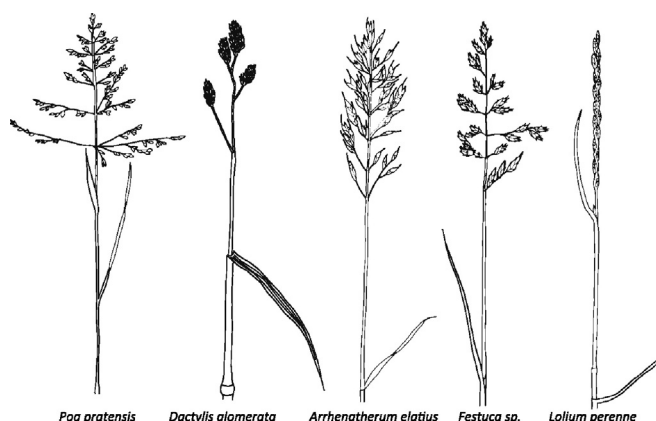
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HIGHLIGHTS

- Three different approaches were combined to examine a grass pollen season.
- The daily course of pollen concentrations and symptom data is comparable.
- Not all of the observed grass species seem to contribute to the main pollen season.
- Grass species flowering before and after the main season cause less allergenic burden.

GRAPHICAL ABSTRACT



Poa pratensis *Dactylis glomerata* *Arrhenatherum elatius* *Festuca* sp. *Lolium perenne*

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ABSTRACT

Background: Grasses (Poaceae) are one of the largest plant families and are distributed worldwide. Grass pollen allergy is one of the most important pollen allergies affecting large parts of the population worldwide. The grass pollen season itself is special since it is caused by the flowering of various grass species that present unique profiles of allergenicity, which assumingly plays a significant role and impact on grass pollen sensitization profiles for the allergy sufferer. The aim of this study, conducted in Vienna, 2014, was to analyze the possible contribution of prevalent grass species to the grass pollen season and to the symptom load of grass allergy sufferers.

Methods: This was the first study that combines phenological observations (i.e. grass species and their flowering periods) with aerobiological measurements (i.e. daily grass pollen concentrations) in concert with allergic symptoms from local users of the Patient's Hayfever Diary (symptom load index calculation).

Results: Both the pollen concentrations and the symptom levels were higher in the first half of the main grass pollen season and therefore show the highest impact on pollen allergy sufferers. Of important note were the following species that are widely distributed in Vienna: Kentucky bluegrass (*Poa pratensis*), orchard grass (*Dactylis glomerata*), false oat-grass (*Arrhenatherum elatius*), fescue grass (*Festuca* sp.) and perennial rye-grass (*Lolium perenne*).

Abbreviations: SLI, symptom load index; EAN, European Aeroallergen Network.

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Conclusion: Monitoring different grass species provided evidence for varying contribution in pollination across the main grass pollen season and highlighted the significance this impact may have on pollen allergy sufferers.

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1. Introduction

Grasses (Poaceae) are one of the largest plant families in the world with nearly ubiquitous distribution. With > 10,000 species the Poaceae family is the fifth-largest plant family in the world (The Angiosperm Phylogeny Group, 2009) and grass dominated habitats cover up to 40% of the earth's vegetation (Gibson, 2009). Moreover, the Poaceae family includes the three most important crops in the world wheat (*Triticum aestivum*), maize (*Zea mays*) and rice (*Oryza sativa*) as well as other productive species (Grass Phylogeny Working Group II, 2012). However, grasses are also the most important aeroallergens worldwide with sensitization rates up to 30% depending on climate and region (Andersson and Lidholm, 2003; Kleine-Tebbe and Davies, 2014). Up to now, eleven different groups of grass pollen allergens have been identified consisting of major allergens (>50% sensitization rate) and minor allergens (<50% sensitization rate) (Andersson and Lidholm, 2003). In Austria, grasses have the highest sensitization rates and >50% of all pollen allergy sufferers are sensitized in the eastern part of the country to grass pollen (Hemmer et al., 2010). A major problem is the gap in knowledge that exists on the contribution of single grass species to allergic reactions and sensitization profiles of people concerned. Extensive cross-reactions among allergens of different grasses are known (Johansen et al., 2009) as well as the different allergenicity of single grass species (Bullimore et al., 2012). However, it remains unclear if and how those species are responsible for the allergenic burden under natural conditions. An evaluation of different grass species within the pollen counting routine is hardly feasible due to the similar morphology of grass pollen grains (Perveen, 2006) leading to subjective interpretations and species determination in the optical light microscope (Andersen and Bertelsen, 1972). A promising approach to define pollination periods of different species during the grass pollen season is phenology: the visual observation of flowering conditions of plants in the field (Nord and Lynch, 2009).

However, phenological studies in the field of aerobiology are rare since they are time consuming and require deep botanical knowledge. Up to now, only a few studies from the Mediterranean area of Europe had a focus on the flowering of different grass species, in combination with airborne grass pollen concentrations. In Italy, the most prevalent grass species were observed in three different regions to display their pollination periods with the regional averaged pollen concentrations (Frenguelli et al., 2010). More local approaches were undertaken in the city of Badajoz (Tormo et al., 2011) and in and around the city of Cordoba in Spain (León-Ruiz et al., 2011; Cebrino et al., 2016). However, both studies only presented the relation between airborne grass pollen concentrations and the flowering of different grass species but did not analyze any potential impact on pollen allergy sufferers. Within this pilot study the grass pollen season 2014 in Vienna was observed for the first time in a central Europe location using a phenological approach. Furthermore, phenological data, daily mean grass pollen concentrations and symptom data from the Patient's Hayfever Diary was compared for the first time to improve the knowledge about the grass pollen season.

2. Material and methods

2.1. Phenology

Field observations to identify the flowering periods of different grass species were performed twice a week from two locations in the area of Vienna. To cover a representative range of grass species, extensive

observation sites of different urban habitats were chosen. The western location "Steinhofgründe" is a natural monument next to the surrounding woods of Vienna and represents a more natural habitat, whereas the second area "Neue Donau/Wasserpark" is located in the eastern part of Vienna and consists of a public park, riverside vegetation as well as rail track vegetation and therefore can be regarded as more urbanized. Both observation areas are located in the city borders of Vienna and are in close distance to the pollen monitoring station (Fig. 1). At both observation sites a total area of about 40,000 m² per location has been taken into account to assess the distribution of each grass species observed. Ten random fields per location with a surface of 4 m² were studied for the phenological observations. However, it has to be mentioned that the location of the random fields could be set wider apart due to governmental lawn mowing activities (see Limitations). To define the pollination periods of each grass species five different phenological phases have been used. These phases were translated into international BBCH phenological phases for cereals (Lancashire et al., 1991), which also belong to the sweet grass family (Poaceae). In essence, the approach follows León-Ruiz et al. (2011) with minor changes concerning the phenological phases 1–3 (Table 1). Those changes were performed to improve the match with aerobiological sampling and to increase the chance to catch a second flowering (re bloom). This results in (1) delaying the defined start of flowering (25% of individuals have to flower) when pollen is more likely to occur in the air, (2) prolonging the end of the season to detect reblooms (25% of individuals are still flowering) and (3) defining the full flowering condition as it is for cereals (50% of individuals flower; Table 1). Moreover, at least > 25 individuals per species and defined surface were considered to avoid recording only poorly distributed grasses within the respective observation area (Frenguelli et al., 2010).

2.2. Aerobiology

Daily airborne pollen concentrations were evaluated with a volumetric pollen and spore trap of the Hirst design (Hirst, 1952). The analyzed data of the Vienna pollen trap is also included in the EAN and therefore underlies specific minimum recommendations (Galán et al., 2014) to ensure high data quality. The EAN database holds about 400 active pollen-monitoring sites in and beyond Europe. The pollination period of the grass pollen season was defined by using the standardized season definition of EAN. Hence, the season starts at the day with 1% of the cumulative annual total grass pollen count and ends at the day of 95% of the total annual pollen count.

2.3. Symptom data

Symptom data was requested from the Patient's Hayfever Diary which is a free web-based, online diary recording symptoms of users who suffer from pollen allergies. This pollen diary is a highly practicable tool for scientists and pollen allergy sufferers (Bastl et al., 2014; Karatzas et al., 2013; Voukantsis et al., 2013). The access is possible via the following website (<https://www.pollendiary.com>) or the "Pollen" mobile application in Austria (Kmenta et al., 2014). However, the Patient's Hayfever Diary is also available in twelve other European countries. Users fill in a validated questionnaire and indicate the symptom severity of eyes, nose and lungs including medication use. On this basic information a total symptom score can be calculated. For the purpose of this study, the data of all users from Vienna exhibiting a positive background correlation to grasses during the grass pollen season in 2014 were

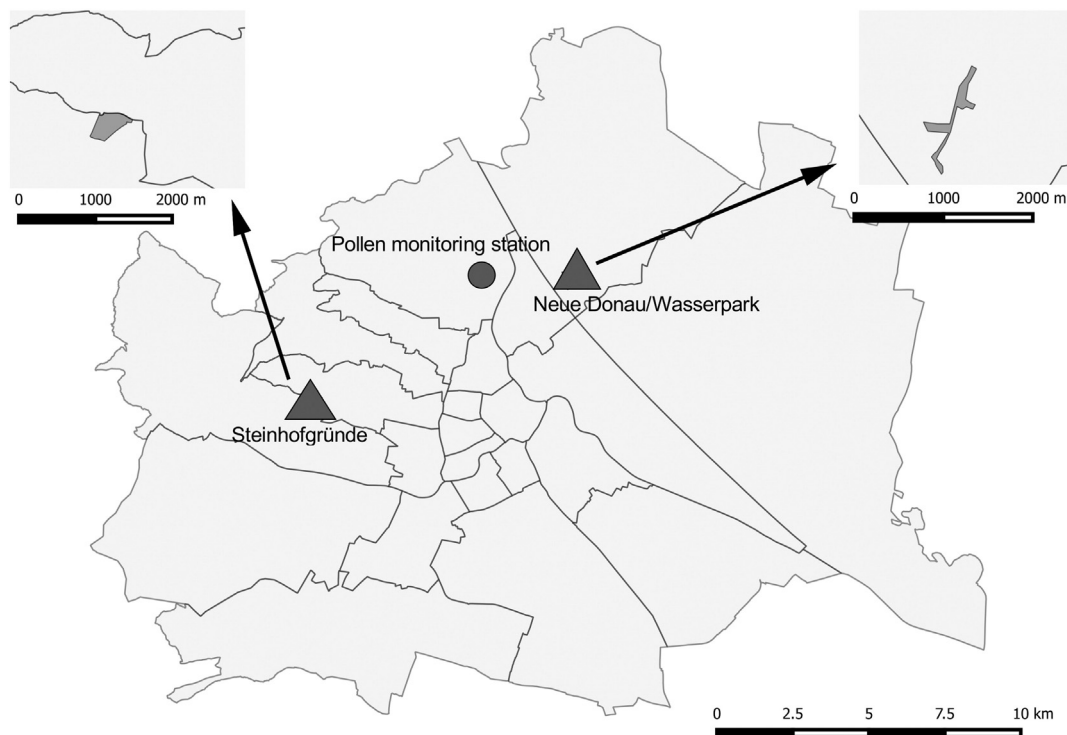


Fig. 1. City map of Vienna including the locations of the phenological observation sites (gray triangles, detailed areas in the upper corners) and the pollen monitoring station (gray circle).

included. Only users with a minimum of 10 entries during the main grass pollen season have been included into the study. Moreover, users with a positive background correlation to birch pollen were excluded, thus to avoid unrealistic symptom loads in the beginning of the grass pollen season due to poly-sensitization and a short overlap of birch and grass pollen season. Afterwards, daily symptom load indices were calculated as described in Bastl et al. (2014). Thus, the total symptom scores (including all organs and medication use) of all user entries were normalized to attain daily mean values between 0 and 10 for the respective time period of the grass pollen season.

2.4. Statistics

For statistical analysis software R in version 3.2.2 was used. Pollen data and symptom data was compared with a linear correlation model. A Shapiro-Wilk normality test showed no significant deviation from normality with a P-value of 0.41. The residual of this model was used in an analysis of variance (ANOVA) containing the most abundant grass species from phenological observations to explain if single grass species have additional impact on symptom data. Furthermore, a second analysis of variance (ANOVA) was used to test the performance of these species during the entire season with grass pollen concentrations only. Shapiro-Wilk normality tests showed no significant deviation from normality with a P-value of 0.36 for the residuals from the first model as well as no significant deviation from normality with a P-Value of 0.89 for the second model with the square root of the pollen concentrations.

3. Results and discussion

3.1. Phenological observations

Phenological observations started in the mid of April (week 15) and lasted until mid of August (week 33). In total, the twelve most prevalent grass species were observed at both observation areas (Table 2). The grass pollen season started with the flowering of meadow foxtail grass (*Alopecurus pratensis*) and sweet vernal grass (*Anthoxanthum odoratum*) in the second week of April (Fig. 2). In the beginning of May Kentucky bluegrass (*Poa pratensis*) and orchard grass (*Dactylis glomerata*) started flowering and were major contributors of the first and highest peak within the grass pollen season (Fig. 2). Within the period of the first peak, the first indication of flowering was observed for false oat-grass (*Arrhenatherum elatius*), Yorkshire fog (*Holcus lanatus*) and fescue grass (*Festuca* sp.) and initiated the main pollination period in Vienna ranging from the mid of May until the end of June (Fig. 2). Moreover, perennial rye-grass (*Lolium perenne*) started flowering later within this time frame and produced the longest pollination period of

Table 1

Phenological phases for grasses used in this study compared to the phenological phases of León-Ruiz et al. (2011).

Phenological phases (León-Ruiz et al., 2011)	Phenological phases (this study)
Phase 0 (BBCH 60): period of time between plant emergence and the start of flowering	Phase 0 (BBCH 60): period of time between plant emergence and the start of flowering
Phase 1 (approx. <BBCH 62): start of flowering phase - begins with the first open florets and ends with 25% open florets.	Phase 1 (approx. <BBCH 63): start of flowering phase - reached when first anthers in 25% of the observed individuals are extruded.
Phase 2 (approx. <BBCH 67): Full flowering phase - time period in which between 25% and 75% of the florets are open.	Phase 2 (BBCH 65): Full flowering phase: - in 50% or more individuals anthers are extruded and fully developed.
Phase 3 (approx. <BBCH 69): End of flowering phase - starts when 75% of florets are open and ends when all florets have released all their pollen grains.	Phase 3 (approx. <BBCH 68): Second flowering phase - >50% of the individuals are withered, 25% or more are still in flowering condition.
Phase 4 (BBCH 69): Fructification phase - starts when all florets have released all their pollen grains.	Phase 4 (BBCH 69): Fructification phase or end of flowering phase - starts when all anthers are withered.

Table 2
Observed grass species in the phenological areas including start and end of the pollination period, the distribution at the observation sites (1 only appeared in one area; 2 appeared in both areas) as well as the overall percentages of grass species (all surfaces included).

Observed grass species	Start of the pollination period	End of the pollination period	Distribution (appearance at phenological sites)	Overall percentages of grass species (all surfaces included)
<i>Alopecurus pratensis</i>	Week 15	Week 18	1	2.5%
<i>Anthoxanthum odoratum</i>	Week 15	Week 19	1	2.0%
<i>Poa pratensis</i>	Week 17	Week 23	2	15.8%
<i>Dactylis glomerata</i>	Week 19	Week 24	2	17.2%
<i>Bromus hordeaceus</i>	Week 18	Week 24	2	4.9%
<i>Arrhenatherum elatius</i>	Week 21	Week 27	2	13.8%
<i>Festuca</i> sp.	Week 21	Week 27	2	10.3%
<i>Holcus lanatus</i>	Week 21	Week 26	1	3.0%
<i>Lolium perenne</i>	Week 23	Week 30	2	16.7%
<i>Phleum pratense</i>	Week 25	Week 28	1	3.9%
<i>Agrostis capillaris</i>	Week 26	Week 29	1	5.4%
<i>Cynodon dactylon</i>	Week 28	Week 33	1	4.5%

all species observed ranging from the beginning of June until the beginning of August (Fig. 2). Common bent grass (*Agrostis capillaris*) and Timothy grass (*Phleum pratense*) started flowering in the mid/end of June and therefore were the most important contributors in the end of the grass pollen season (Fig. 2). Bermuda grass (*Cynodon dactylon*) appeared last and started flowering in the mid of July until the end of our observation period (Fig. 2). A full flowering period could not be observed for soft brome grass (*Bromus hordeaceus*), since only minor parts of the individuals were in flower during the season (Fig. 2). Only half of the grass species included in this study could be observed at both phenological monitoring sites (Table 2). Detailed information about the phenological phases and the distribution in the field of the different grass species (in percentages) is presented in Table 2 and Fig. 2. Only the phenological phases where pollination is likely (phase 1–3; see Table 1) have been included in Fig. 2.

3.2. Pollen concentrations in the ambient air

The main grass pollen season in 2014 was calculated after the season definition of the EAN (see Materials and methods section) started on the

30th of April and ended at 19th of July (Fig. 2). The absolute peak pollen concentration occurred on the 20th of May and reached a maximum daily average value of 127 pollen grains per m³. Another day with a second peak pollen concentration (>100 pollen grains per m³) was observed on the 23rd of May within the same week. In the period before and after the main grass pollen season (April and August) only minor concentrations of <10 pollen grains per m³ occurred (data not shown).

3.3. Daily symptom data

In total 325 users entered data during the main grass pollination period in 2014 and produced 7.500 symptom data sets that were included into this study. About 26% of all users recorded symptom data only in the first part of the main grass pollen season and entered data from the beginning of May until the first peak in the middle/end of May. In comparison 55% of all users entered symptom data starting with the first peak in the end of May until the last peak in the pollen concentrations (above 30 pollen per m³) in the end of June. In addition 19% of the total user number entered symptoms through the whole main grass pollen season. To compare daily pollen concentrations and symptom

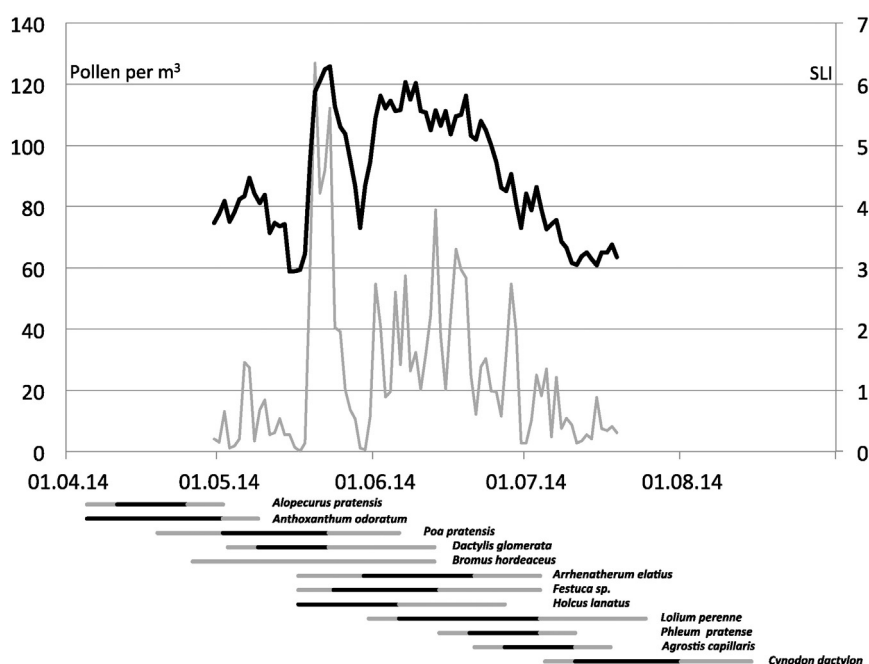


Fig. 2. Comparison of daily grass pollen concentrations per m³ (left y-axis; gray line), daily averaged SLI values from 0 to 7 (right y-axis; black line) and the pollination periods of the different grass species including phenological stages 1–3 (1 and 3 gray horizontal lines; 2 black horizontal lines) during the main grass pollen season in Vienna 2014.

data, daily symptom data entries have been averaged and symptom load indices were displayed for the main grass pollen season. The SLI values in the beginning of the grass pollen season, from the 30th of April until the first peak in the end of May, stay below 4.5 (Fig. 2). During the main pollination period from the end of May until the end of June the SLI values increase and range between 4.5 and six with a maximum value of 6.29 on the 23rd of May (Fig. 2). In the beginning of July the SLI values decrease again staying below a value of 4.5 and announce the end of the grass pollen season (Fig. 2).

3.4. Statistical results

The linear correlation model shows a significant correlation between the crowd-sourced symptom data of the SLI and the pollen concentrations per m³ of the ambient air during the main grass pollen season in 2014 (Fig. 3, Table 3). The additional analysis of variance was performed with the residual of this model for grass species with abundant distribution at the phenological sites (Table 2) and indicates significant correlations for Kentucky bluegrass (*P. pratensis*), orchard grass (*D. glomerata*), and false oat-grass (*A. elatius*) whereas perennial rye-grass (*L. perenne*) did not show a significant correlation (Table 3). Moreover, a second analysis of variance shows notable correlations regarding the pollen concentrations per m³ of air and these grass species (Table 3). Kentucky bluegrass (*P. pratensis*) is the only species, which does not show a significant correlation here. Since the pollination periods of false oat-grass (*A. elatius*) and fescue grass (*Festuca* sp.) proceeded coextensively it was not possible to implement both at the same time into the variance analysis due to the collinearity of the variables and the limited number of observations. However, if both grass species are included separately in the models they perform in the same way (data not shown).

3.5. Interpretation and discussion

This pilot study analyzed the relationship between the varying contributions in pollination from various grass species, across the main grass pollen season, and highlighted the significance this may have for pollen allergy sufferers through linking the prevalence of grass species across this season with real-time symptomatic data. The study design applied here can be easily transferred to other European locations since the databases used comprise datasets from large parts of Europe. The statistical analysis showed a significant correlation between daily

Table 3

P-values of the linear correlation model, the analysis of variance from the residuals of this model with the most prevalent grass species as well as P-values from the second analysis of variance regarding the daily pollen concentrations.

P-value of the linear regression model SLI/sqrt pollen concentration: $2 \times 10^{-16}***$		
Grass species	P-values ANOVA linear regression model residuals	P-values ANOVA square root of pollen concentrations
<i>Poa pratensis</i>	$2.392 \times 10^{-07}***$	0.296219
<i>Dactylis glomerata</i>	$1.110 \times 10^{-05}***$	$7.084 \times 10^{-05}***$
<i>Arrhenatherum elatius</i>	$5.115 \times 10^{-06}***$	$2.225 \times 10^{-10}***$
<i>Lolium perenne</i>	0.125	0.001009**

Significance codes: 0 ****, 0.001 ***, 0.01 **, 0.05 *, 0.1 ., 1 .

SLI values and grass pollen concentrations within the main grass pollen season (Fig. 3, Table 3). Previous studies showed correlations between allergic symptoms and grass pollen concentrations as well (Caillaud et al., 2012; Feo Brito et al., 2010).

Above all, some grasses seem to be more important than others regarding their distribution at the phenological observation sites (Table 2) as well as in the statistical analysis (Table 3). Results presented herein suggested that the most prevalent grass species in both observation sites across the pollen season were: Kentucky bluegrass (*P. pratensis*), orchard grass (*D. glomerata*), false oat-grass (*A. elatius*), fescue grass (*Festuca* sp.) and perennial rye-grass (*L. perenne*) (Table 2). The five aforementioned grass species appeared in higher numbers at all surfaces evaluated (Table 2) as well as in the whole area of the observation sites (pers. observation). Moreover, these grass species have high distribution rates in the whole area of Vienna based on 150 years of vegetation survey data (Adler and Mrkvicka, 2003). Although soft brome grass (*B. hordeaceus*) was present in significant numbers at both observation sites, a full flowering period could not be observed and therefore the impact within the main grass pollen season was subsequently low. Moreover, it is known that the pollen production of soft brome grass as an annual grass is low (Prieto-Baena et al., 2003; Aboulaich et al., 2009) and therefore unlikely to be a main contributor to the grass pollen season.

Statistical analysis supports the importance of the five aforementioned grass species, which corresponded with a high distribution count in Vienna (Table 2; Adler and Mrkvicka, 2003). The early flowering species of Kentucky bluegrass, orchard grass, false-oat-grass and fescue grass indicated an additional impact on the symptom load index (Table 3), whereas perennial rye-grass did not present any significance. This could be explained by the fact that the main pollination period of the four grasses corresponded with the highest SLI values and the highest pollen concentrations (Fig. 2). Moreover, studies have shown that symptom scores follow a linear trend at the beginning of the season and reach a plateau at a certain point within the season (Caillaud et al., 2012). This fact would support the statistical analysis and explain the weak response of perennial rye-grass on the symptom data, which is flowering later in the main grass pollen season.

When comparing daily pollen concentrations with the five prevalent grass species all of them exhibited a significant correlation with the pollen concentrations except for Kentucky bluegrass. Since the pollination period of Kentucky bluegrass started earlier than the other grasses when daily pollen concentrations were low, a lower correlation and therefore a lower contribution to the pollen flight is reasonable. The positive correlation of Kentucky bluegrass with symptom data could be explained by an anticipation effect of allergic symptoms before the increase of daily pollen concentrations. Possible explanations for such an effect would be differences in capture height of the pollen monitoring station (see Limitations) or allergen released in the ambient air before pollen grains were detected in the pollen monitoring station already having an impact on the allergic burden (Bastl et al., 2016). Orchard grass appeared to be one of the main contributors of the grass

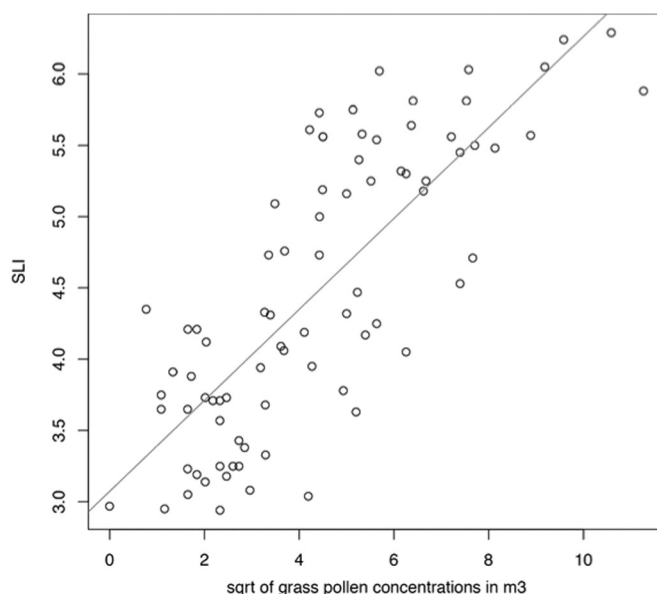


Fig. 3. Linear correlation model of daily SLI observations (y-axis) and the square root of daily pollen concentrations per m³ (x-axis).

pollen season in Vienna (Fig. 2, Table 3). Also in the studies of Cordoba, orchard grass was one of the main contributors to the grass pollen season (León-Ruiz et al., 2011; Cebrino et al., 2016). Grass pollen production of different species clearly had varying impact on the main grass pollen season. The pollen production of several grass species has already been investigated in Spain and Morocco (Prieto-Baena et al., 2003; Aboulaich et al., 2009). However, most of the species included in these studies are not native to central Europe and although different species of the same genus produce high amounts of pollen (e.g. *Arrhenatherum album* or *Lolium rigidum*), further investigations on pollen production for central European grass species are necessary to ascertain whether species native to central Europe perform in the same way.

Up until now eleven different allergen groups were detected for grasses (Andersson and Lidholm, 2003). Although group 1 and group 5 allergens are considered as major allergens within the Poaceae family, show high cross-reactivity rates within their allergenic groups and explain pollen sensitization (Andersson and Lidholm, 2003), patients can also be sensitized to minor allergens (Schmid-Grendelmeier, 2010). There are also differences in allergen content of the ambient air (Phl p 5), grass pollen concentrations and symptom loads on a European scale (Bastl et al., 2016; Buters et al., 2015). Moreover, recent studies highlight the unique biochemical profiles for each different grass species (Bullimore et al., 2012) and varying amounts of major allergen content (Moingeon et al., 2008). Thus, in addition to the importance in cross-reactivity of major allergen groups, minor allergens and the contribution of unique IgE epitopes from different grass species themselves has the propensity to impact individual symptom severity in grass pollen allergy sufferers. This question is also essential regarding specific immunotherapy. Since a long time scientists and pharmaceutical companies argue whether it is beneficial for patients to use a single “exemplar” grass or a multiple “broad-spectrum” grass mix for successful immunotherapy (Kleine-Tebbe, 2008). According to the literature, both approaches show conformable results (Moingeon et al., 2008; Martínez-Cócerca et al., 2010; Bullimore et al., 2012; Aleksic et al., 2014). However, bearing in mind the variety of grass species that contribute to the grass pollen season, including minor allergens and the differing amounts of major allergens, a multiple “broad-spectrum” grass approach will undoubtedly mimic and reflect a more natural exposure condition and therefore be more beneficial for grass pollen allergy sufferers.

3.6. Limitations

Since every methodology has its limitations the following points that may have had an impact on the results should be mentioned. Green (grassy) areas in a metropolis like Vienna are limited and subject to many changes, among them construction work, governmental mowing activities, management and economic reasons (sale, private properties) to refer only to some of them. All of them are connected with the disappearance of grasslands and green areas in the city. These activities have an effect on phenological observations as well (available areas for observations) and could lead to a loss of (smaller) observation sites. Therefore, it has been taken care to observe only two, but preferably large areas in this pilot study, which are representative for the grass flora of Vienna (Adler and Mrkvicka, 2003) to enable flexibility to move to another spot still available within the same region (random fields) and to include as many grass species as possible. However, during the study period no grass areas included in this study vanished, most were only subject to governmental mowing activities.

The pollen data obtained is following the minimum recommendations (Galán et al., 2014), but of course also aerobiological measurements underlie certain limits and represent point measurements. Pollen traps are positioned usually on a rooftop like the Vienna trap – a location ideal to assess pollen concentrations for a region. However, the pollen concentrations are assessed in a height of 20 m and not on a level relevant for pollen allergy sufferers. Although there is contradiction in literature whether and how pollen concentrations differ on

rooftop and nose level, the indications for a real difference depending on the pollen type should not be neglected (Rantio-Lehtimäki et al., 1991; Spiekma et al., 2000; Zwander, 1985, pers. observation). It is fairly possible that grass pollen data obtained on a rooftop level diverges significantly from those on nose/ground level especially in terms of pollen loads.

Although only users with a minimum of 10 entries were included in the study, there is no homogenous use of the Patient's Hayfever Diary through the whole grass pollen season. This means not all users entered symptom data over the whole study period. There is a number of explanations for this fact: July is a holiday month and a fraction of users could not enter data for Vienna during their vacation and/or not all users experience symptoms through the whole pollination period of grasses. Different sensitization levels and a personally varying burden were already observed and described (Kmenta et al., 2014) and may also be part of an explanation for this. Still users and their allergies remain unknown for the study, as the Patient's Hayfever Diary conforms to data security rules and does not ask compulsory for any personal data but an email address only (if wished). We see symptom data generated here as crowd-sourced data with its advantages (easy and fast access, validity through high usage) and disadvantages (low to hardly any information on the characters of the sample population).

4. Conclusion

A deep understanding of the botanical background of the flowering grasses, e.g. recording grass species with a high pollen production and determination of grass species of high allergenicity, is the baseline for diagnosing and treating pollen allergy symptoms of grass pollen allergy sufferers. Local expertise is strongly needed in order to determine a range of grass species that are of high importance for a specific region, whereas certain grass species will play a different role in other regions.

Results of this first multi-approach study underline the importance in the plethora of grass species that are prevalent across the grass pollen season and the subsequent impact this may have on allergy sufferers affected.

Statement on conflict of interests

Allergy Therapeutics plc. (FA74409001) provided financial support of this project.

Maximilian Kmenta reports no conflict of interest.

Katharina Bastl reports no conflict of interest.

Matthias Kramer is an employee of Allergy Therapeutics plc., a manufacturer of immunotherapy products.

Simon Hewings is an employee of Allergy Therapeutics plc., a manufacturer of immunotherapy products.

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