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DATA ARTICLE

Reviewing published and grey literature in local European languages to supplement existing databases on floral resource traits

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Abstract

1. The aim of the study was to collect data on plant phenology, density of flowers and production of floral resources in European countries, using published and grey literature written in local languages.
2. The search was conducted in 11 European languages (Danish, Dutch, French, German, Greek, Italian, Norwegian Bokmål, Portuguese, Romanian, Spanish and Swedish) and included published and unpublished data from local journals, books, databases or master and doctoral theses.
3. The collection contains 2382 records for 1132 plant species from 113 families. Most of the data collected is on flowering phenology, with a relatively large amount of data on nectar/sugar production and less on pollen production and floral density (1474, 1141, 325 and 152 records, respectively).
4. Our study is unique in collecting data on floral resource traits in local European languages. The data collected are a valuable addition to existing floral resource trait databases and can help to quantify the floral resources available to pollinators

and other organisms that depend on them for food in different habitats and ecosystems. At the same time, our collection, in combination with other databases on floral resource traits, allows the identification of plant genera and families for which information is scarce, as well as the best-studied plants and countries where research on floral resource traits has a long tradition.

5. Synthesis and applications. Our research shows the value of using data published in local languages, often as grey literature, especially when building ecological databases of various kinds. Much of the basic data we collected on floral resource traits is available in literature published long ago, making it even more difficult for the research community to access. We discussed several technical issues that can be encountered when collecting such floristic data, especially if the data are to be further used in modelling.

KEYWORDS
floral resources, flowering phenology, nectar production, pollen production, sugar production

1 | INTRODUCTION

The most important global effect of climate change is to affect the phenologies (Amano et al., 2010; Cleland et al., 2007; Hassan et al., 2024; Pau et al., 2011; Wolkovich et al., 2013; Wudu et al., 2023) and geographical ranges (Chuine, 2010; Ettinger et al., 2021; McNichol & Russo, 2023; Rubenstein et al., 2023; Thuiller et al., 2008) of plant species. Shifts in both can have cascading effects on ecosystems (Gallinat et al., 2021; Petanidou et al., 2014; Walther, 2010; Wolkovich et al., 2013). Of particular importance in this respect are plant-pollinator interactions (Gérard et al., 2020; Memmott et al., 2007; Obeso & Herrera, 2018; Trunschke et al., 2024; Whipple & Bowser, 2023). Appropriate decision-making processes and conservation policies at regional and local levels are therefore needed to avoid disrupting the sustainable cycle of natural ecosystem processes in different habitat types and across landscapes and countries. This requires a better understanding of both the seasonal dynamics of floral resource production as well as the environmental influences on these patterns. Modelling has become a powerful tool in this regard (Park et al., 2019; Park & Mazer, 2018); however, it requires integrating different types of data on floral resource traits, and thus may often be hampered by significant gaps in the essential input data (Davis et al., 1998; Hassan et al., 2024). This includes gaps in our, often basic, knowledge on flowering phenology (dates and drivers), floral density and production of floral resources for many important plant species, including trees. One of the limitations is that much of this important data may have been published in local languages and/or are archived in local repositories, making the ecological data publicly unavailable to researchers who are not native speakers of these languages. Such a limitation is particularly pronounced in studies where biodiversity data of different types have been collected for pattern testing (Amano et al., 2023; Angulo et al., 2021; Couée, 2024; Hannah et al., 2024; Konno et al., 2020). This issue was also raised in a review of the impact of global change on plant range shifts (Rubenstein et al., 2023).

Developing databases that collect data on floral resource traits at regional, national or continental levels is an important step towards better understanding changes in floral resource production at landscape and ecosystem scales. Such databases are essential for the development of tools for modelling these processes. Recently, there has been significant progress in this area. This includes the reports focusing on one of the floral resource traits, such as floral density (Baude et al., 2015), nectar production (Baude et al., 2016) and pollen production (Wright et al., 2024) of plants in the UK, sugar production in urban green spaces in the UK (Tew et al., 2021, 2023) or flowering phenology of nectariferous species in northwestern Patagonia in Argentina (De Groot et al., 2023) and in Greece (Petanidou et al., 1995; Petanidou & Smets, 1995), as well as multi-trait databases of Filipiak et al. (2022) and Baden-Böhm et al. (2022). Supplementing these databases with published and grey literature written in local languages would add great value to the global collection and allow rigorous testing of patterns in space and time.

This database is, to our knowledge, the first attempt to collect data on floral resource traits by studying literature and local sources of information in the multitude of national languages across Europe. The database of floral resource traits by Filipiak et al. (2022) clearly showed that some European countries were over-represented, while others were under-represented in this respect. One of the possible reasons for this was the authors' limited access to literature published in local European languages. Filipiak et al. (2022) also showed that valuable data on floral resource traits, such as flowering phenology and floral resource production, are available in early scientific reports from the 1980s or 1990s, mainly written in national languages and published in national journals. These findings inspired our research, which aimed to collect data on floral resource traits from the published and grey literature in national languages to (i) complement existing databases and (ii) be able to identify the real knowledge gaps and drive further research. Our database thus illustrates both the great value of local and grey literature data, some of which was produced decades ago and the challenges and difficulties in studying such data.

2 | MATERIALS AND METHODS

The study was carried out as part of the Horizon 2020 Better-B project, one of the objectives of which is to estimate landscape pollinator carrying capacity based on dynamic floral resource models, which are capable of predicting patterns of floral resource production in space and time. The dynamic floral resource models rely heavily on data on floral resource traits, such as those collected by Filipiak et al. (2022). Ziółkowska et al. (2025) identified important gaps in the input data for floral resource modelling, which we aimed to fill by conducting published and grey literature searches in local European languages.

The retrievals were carried out in Danish, Dutch, French, German, Greek, Italian, Norwegian Bokmål, Portuguese, Romanian, Spanish and Swedish. In addition, local data published in English and not included in the Filipiak et al. (2022) database were also included. The following search strategies were used:

- Own data and/or knowledge in others' data.
- Searching Google, Google Scholar, Scopus, Web of Science, national libraries, government agencies, local websites and repositories, using the translation of keywords used by Filipiak et al. (2022) into local languages.
- Asking local researchers publishing in the field for any published studies or grey literature.
- Searching in books dedicated to the topic and published in local languages.

The types of information sources we searched included publications, books, master's and doctoral theses, pilot study results and online databases. All data are presented in Walczyńska et al. (2025).

3 | USAGE NOTES

The data collected include information categorised into four sections: general information, phenology, floral density and production of floral resources (nectar, sugars and pollen). General information refers to the plant species and family, the general type of community studied (whether natural, experimental, urban, ruderal, etc.), the literature reference and URL for the published results, a person in possession of unpublished data, the language in which the data were originally reported, the year of publication (if applicable) and the study site where the data were collected (country and location). Phenology data include the start, peak and end of the flowering period within the studied season and the length of the flowering period. In cases where the exact day within a month was given, this value was converted to the number representing the day of the year. At this point, it is important to mention that the 'start' and 'end' of flowering were not standardised across the studies from which the data were retrieved. Data on floral density include information on the type of floral unit surveyed (flower or the inflorescence), followed by information on the total number of plants per m^2, the number of floral units per m^2 and the number of floral units per plant. Floral resource production is given for the respective floral unit and includes nectar production in mass or volume, sugar concentration and/or sugar production and pollen production in mass, volume or number of grains. The last column contains additional comments if the researcher felt it necessary to add clarifying information.

4 | GENERAL PATTERNS

The database contains 2382 cases and includes 1132 plant species representing 113 families. Of these, 81 are tree species and 541 species are new (see appendix) compared to a database by Filipiak et al. (2022). The original data were collected in natural communities of different types (forest, grassland, heathland, meadow, reserve), in urban areas (botanical garden, city green area, roadside) or derived from different types of cultivated areas and field experiments. In about half of the cases (604), the studies provided complete information on flowering phenology. In many cases, only the month of flowering was given and not the exact date. There are 24 records with combined data on flowering phenology, floral density and nectar/sugar production, 23 records with combined data on flowering phenology, floral density and pollen production and only 7 records with combined data on all floral resource traits studied. A list of information sources used only in the dataset is provided as Data S1.

We did not cover all the European countries and languages in our search, and thus our dataset cannot be treated as a complete, quantitative study for Europe. However, it is an important contribution to the existing knowledge on floral resource traits, which could help to identify knowledge gaps and suggest further research directions. Figure 1 and Table S1 show how, by country of origin of the data, our database complements that of Filipiak et al. (2022). For some countries, such as Belgium, France, Germany and the Netherlands, our study significantly extends the data collected for all or almost all of the floral resource traits studied. In many cases, the data collected in this study are new for the country. On the other hand, the study has shown that there are countries, such as Norway or Portugal, where, at least to our knowledge, no information on floral resource traits studied has been published in the national languages, and for others, the data are quite limited (the reports on the details of the search procedure for each country are available from the authors on request). This does not mean that it is not possible to estimate floral resource production in floras found in these countries, as data on floral resource traits for plants found in these floras may have been collected in other countries. However, such estimates may be hampered by data gaps for certain

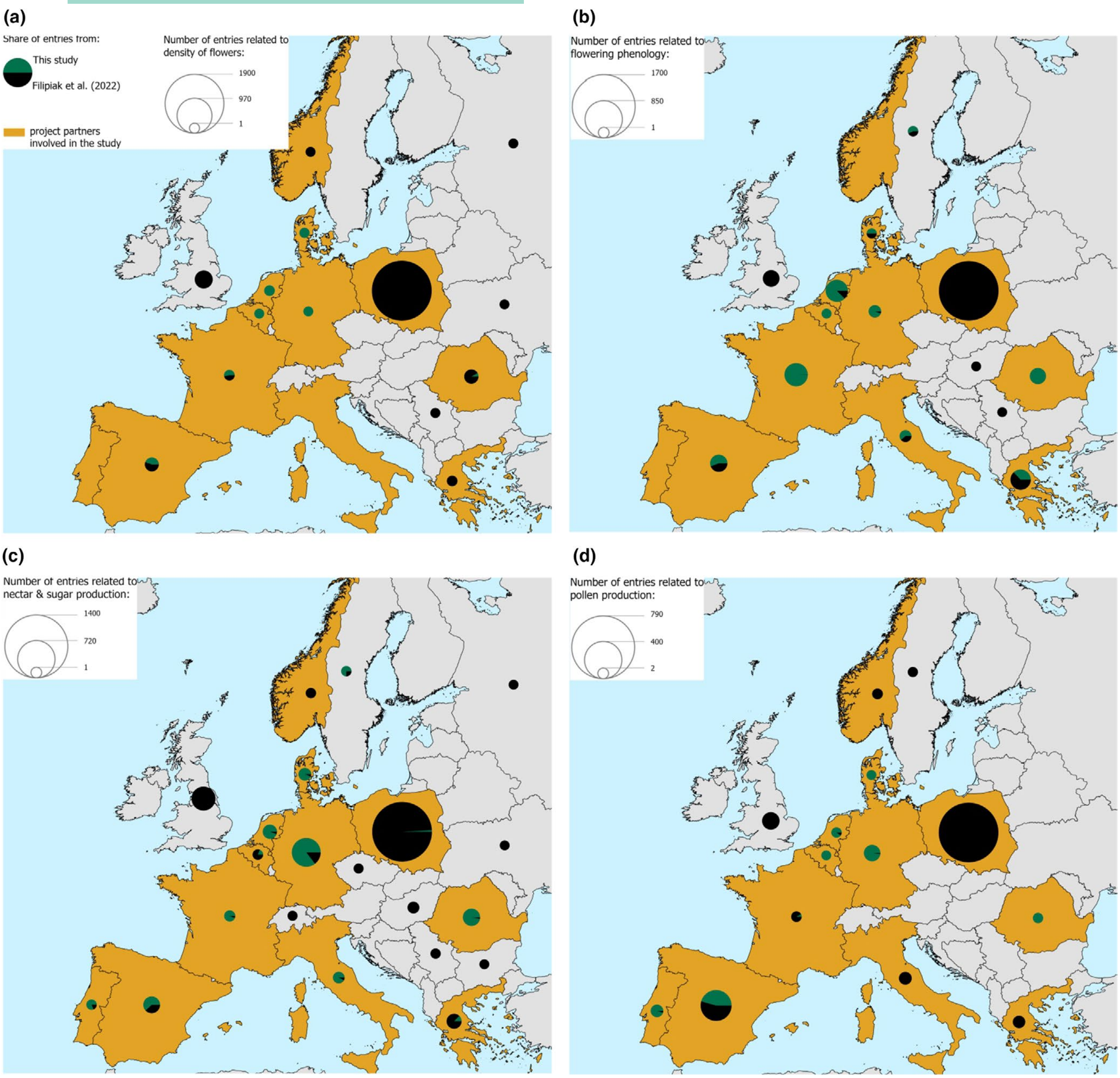

FIGURE 1 Number and distribution of database entries related to (a) density of flowers, (b) flowering phenology, (c) nectar and sugar production and (d) pollen production, compared to the database of Filipiak et al. (2022). Note that the size of pie charts represents different values depending on the data type.

characteristic plants, as well as by the lack of local data, which are often required for model/prediction validation.

A relatively large number of studies on pollen production provide information on the number of pollen grains. However, pollen grains vary in size from a few to >100 μm in diameter, and therefore are highly variable in volume and mass (Faegri & Iversen, 1964). Although studies reporting numbers of pollen grains make the data comparable for a given species between studies, it prevents their use in estimating the quantity of floral resources available in the environment, because the species-specific mass of the pollen grain is usually missing in such studies. This limits the use of this type of data in ecological research. We suggest either the measurement of pollen production in units of mass or volume, or the addition of information on the mass of individual grains to studies on the number of pollen grains. Measurements of floral resource production in either mass or volume units are acceptable if only the unit is consistent for all plant species studied in a given dataset/flora/habitat or ecosystem, and the results can be interpreted correctly in the light of the research question posed. Another difficulty identified is the variety of measurement methods used to determine production levels of floral resources and floral densities, and the lack of clarity in their documentation, which prevents repeatability of research. This often makes it difficult to standardise and correctly interpret the data obtained. Hopefully, the development and dissemination of standardised protocols for measuring floral traits, such as those proposed by Michelot-Antalik et al. (2025), will help to improve this issue.

There were a number of reports that we could not use because the production of floral resources was reported in terms of ranks (i.e. where a given rank represented a particular class of production values) rather than real values. As there is no universal method for decoding such data, they were not useful for our database, in which actual floral resource production values are used to support detailed, quantitative modelling of changes in floral resource production over space and time. However, the ranked production or classes of production values may be useful for informational purposes, as well as for calculating so-called 'potential production' values, defined as the product of species cover (within a given habitat or research plot) and the class mean production value. Potential production values can be used to assess relative differences in floral resource production among habitats or plots over time and space (De Schuyter et al., 2024).

It is important to note that the compilation of flower phenology data across Europe has not been the aim of this study. Flowering phenology data can be obtained from various national or pan-European databases on plant phenology, such as the Pan-European Phenology Database PEP725 (http://www.pep725.eu/). Ziółkowska et al. (2025) combined flowering phenology data from different sources to build floral resource models for a variety of plants. Most of the flowering phenology data in our database are accompanying data for other measurements, that is, they have been recorded in association with measurements of resource production or floral density. The exceptions are the data on flowering phenology (beginning, end and length of flowering) for 454 plant species from the Apibotanica database (apibotanica.inra.fr), which is the palynological and botanical inventory of the INRA (collected in Magneraud, near Surgères in Charente-Maritime in France), and the data on flowering phenology (beginning, peak, end and length of flowering) for 133 plant species from the doctoral thesis of Petanidou (1991). The flowering phenology data collected in our database thus serve as an important addition to existing phenology databases. Importantly, some data in our database are approximate, as they are given to the nearest month. Although these data cannot be used directly for modelling, they are important for validating predictions.

5 | RELATED WORKS

To better understand the impact of changes in the availability of floral resources throughout the year at the landscape or ecosystem scale on pollinators and other consumers, it is necessary to collect detailed, quantitative data on floral resource traits. The modelling framework proposed by Ziółkowska et al. (2025) combines information on floral resource production from individual floral units with information on density/abundance of floral units per unit area and information on flowering phenology. This allows calculation of daily nectar, sugar and pollen production throughout the year at habitat and landscape/ecosystem scales. The modelling of flowering phenology is achieved by combining information on flowering time with meteorological data using the location and year of measurement. The underlying databases of the modelling framework are currently based on data compiled by Filipiak et al. (2022), but are considered 'living databases', that is, they can be continuously updated with new data. Our database complements the work of Filipiak et al. (2022) and represents an important step towards filling information gaps for certain plant species, thereby enhancing our understanding of floral resource availability at landscape and ecosystem scales.

AUTHOR CONTRIBUTIONS

Elżbieta Ziółkowska conceived the study. Dirk C. de Graaf secured the funding. Merel Braeckman, Nuno Capela, Daniel Severus Dezmirean, Yoko L. Dupont, Fernando A. Fleites-Ayil, Amelia V. González Porto, Linn F. Groeneveld, Delphine Jullien, Anne Lavalette, Luna Kondrup Marcussen, Claudia Paşca, Theodora Petanidou, Marco Pietropaoli, Demetris Taliadoros, Jolanda Tom, Trudy van den Bosch, Gilles Verbinnen and Matthew T. Webster conducted the investigations and cured data. Aleksandra Walczyńska and Elżbieta Ziółkowska prepared figures and tables. Aleksandra Walczyńska and Elżbieta Ziółkowska drafted the work. Merel Braeckman, Nuno Capela, Dirk C. de Graaf, Daniel Severus Dezmirean, Yoko L. Dupont, Fernando A. Fleites-Ayil, Amelia V. González Porto, Linn F. Groeneveld, Delphine Jullien, Anne Lavalette, Luna Kondrup Marcussen, Claudia Paşca, Theodora Petanidou, Marco Pietropaoli, Demetris Taliadoros, Jolanda Tom, Trudy van den Bosch, Gilles Verbinnen and Matthew T. Webster revised it critically for important content.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

PEER REVIEW

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DATA AVAILABILITY STATEMENT

The collected database is available at https://uj.rodbuk.pl/dataset.xhtml?persistentId=doi:10.57903/UJ/LNZGXM (Walczyńska et al. 2025).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Data S1. List of species not included in the work of Filipiak et al. (2022), but for which information was found by searching databases in local languages.

Table S1. Number of entries related to the studied floral traits, compared for the original database (Filipiak et al., 2022) and the database collected for this study, for different European countries.

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