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Article

Explore the Efficiency of Festuca Species as a Long-Term Data Set in British Isles

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Abstract: We explored the efficiency of *Festuca* species flowering dates from Reading University herbarium (RNG) as a representative of the British Isles plant populations by comparing it to the actual flowering data sets from the Chinnor data set. In order to determine the significant value of the comparison, two samples t-tests were constructed for each species individually to see if there is no significant value between RNG and Chinnor data sets or not. The only years that were presented in both data sets (Chinor and RNG) were depended on this comparison. The result of the two samples equal variances t –test, created a comparison between RNG and Chinnor flowering dates of the selected *Festuca* species: *F. arundinacea*, *F. gigantea*, *F. pratensis*, and *F. rubra*. The total results of all t- test analysis except for *F. rubra* presented significant p- values (<0.05). Herbarium data presented by Reading University herbarium may present a rich resource of flowering date data. Analysis of herbarium data may provide one route to determine the individual phenological responses of different grasses to changing climate.

Keywords: Long–term data sets, Chinnor data set, herbaria data, Phenology, Festuca species

Introduction

Understanding the flowering time of grasses could help manage hay fever or asthma effects which are related mainly to grass pollen allergy. According to Van Vliet, grass pollen is the most important factor causing hay fever especially in Western Europe, because of its high content of allergenic pollen. *Festuca* is considered one of the largest genera of the Poaceae (grass), with wide distribution in temperate and alpine areas [1]. Economically, *Festuca* species are important, especially *F. rubra* (Red *Festuca*), and *F. arundinacea* (Tall *Festuca*) species that are used commonly as a forage for livestock or for fine lawns respectively [2].

Long–term data sets are used to predict climate change impacts on the phenological response of many essential annual activities such as flowering time, animal migration, and fruiting time. Using long term data sets in phenology has been documented over decades concerning climate changes [3].

Phenology, the cycling of life events, is a significant indicator of rising temperatures. Over the last decades, the phenological response has become one of the most significant tools to improve our understanding of the danger of warming on plant population abundance. Phenology, is a significant indicator of rising temperatures [4].

Herbaria have become important resources for studying phenological change as they record the phenological state of specimens of many species collected from a wide range of locations and over long term [5]. Historical records of phenological events such as direct field observations, specimen-based records in biological collections, or dated photographs, have been used in the estimation of the impact of climate change [6].

With this work, we aimed to fulfil the following objectives:

Comparing flowering data herbaria data of Reading University Herbarium (RNG) to the actual flowering data sets from the Chinnor data sets, and to investigate the efficiency of *Festuca* species flowering dates as a representative of the British Isles grass [7].

Materials and Method

The comparison between Reading University herbarium (RNG) and Chinnor flowering dates of the selected *Festuca* species was depended on Cook, which recorded four species: *F. arundinacea*, *F. gigantea, F. pratensis*, and *F. rubra.* All these data sets were converted to Julian date, to select the comparable years. Four species of *Festuca* were considered in this study: *F. arundinacea* Schreb., *F. gigantea* (L.) Vill., *F. pratensis* Huds., and *F. rubra L.* University of Reading herbarium (RNG) was the only source of the selected herbarium specimens to be compared to Chinor herbarium specimens. Thirty-three specimens were recorded from each of Reading university herbarium and Chinor herbarium. In total, 66 specimens were used from the both herbaria in the comparison of this study (Table 1). To ensure the current accepted names of the four *Festuca* species, the Plant List, and the Catalogue of Life were checked. A dissection microscope was used for all species to record the flowering stage accurately during collection seasons. The flowering phase was scored for each specimen, and coded according to the BBCH (Biological Bundesanstalt, Bundessortenamt and Chemical Industry) Scale. This uniform coding system for all plant species (mono-and dicotyledonous) classified Phenological flowering stages. According to the BBCH system, the primary growth stage 6 reflects the development stage of flowering. Within the primary flowering stages are secondary flowering stages. All these stages are numbered from 0 – 9, corresponding to the percentage values of flowering specimens (Table 2).

The comparison between Reading university herbarium and Chinor herbarium was depended on *Cook*, with four selected species: *F. arundinacea, F. gigantea, F. pratensis, and F. rubra*. To conduct the comparable years, all Cook data sets and the selected Reading university data sets were converted to Julians date. Regardless of the number of repetitions of each herbarium specimen (RNG) in a year, only the earliest Julian date was selected. *Festuca* species flowering dates from Reading university herbarium, were compared to the actual flowering data sets from Chinnor to measure its efficiency as a representative of the British Isles plant populations.

There were two major concerns in this comparison, firstly, there was an insufficient amount of first flowering dates (FFDs- code 60) for most of *Festuca* species of RNG. All flowering stages (60-69) have been used. Secondly, Reading University herbarium specimens had many gaps in collection for most of the years, compared to the full data sets of *Cook*. Therefore, the only years that were presented in both data sets were depended on this comparison.

For the comparison purpose, histograms were performed to observe the comparable Julian date of RNG and Chinnor specimens visually. In order to determine the significant value of the comparison, two samples t-tests were constructed for each species individually depending on the following hypotheses:

H0: there is no significant value between RNG and Chinnor data sets

H1: there is significant value between RNG and Chinnor data sets.

Table 1. Number of specimens of selected Festuca species from Reading university herbarium and Number of specimens from Chinor specimens according to Cook et. al. (2012).

Species	**Number of selected specimens from Reading university herbarium (RNG)**	**Number of Chinor specimens (Cook *et. al.* 2012)**	**Total number of specimens**
Festuca arundinacea Schreb.	**5**	**5**	**10**
Festuca gigantea (L.) Vill	**3**	**3**	**6**
Festuca pratensis Huds.	**9**	**9**	**18**
Festuca rubra L.	**16**	**16**	**32**
Total	**33**	**33**	**66**

Table 2. Flowering scores and corresponding phase according to BBCH scale**.**

BBCH	**Phase**
60	Pre-flowering phase (anthers are emerging)
61	Start of flowering phase (10%) of florets flowering
62	20% of florets flowering
63	30% of florets flowering
64	40% of florets flowering
65	50% of florets flowering
67	70% florets are opened and have released pollen grain (flowering finishing)
69	End of flowering (florets are empty mostly, with 10-20-% of florets Still flowering.

Result

Figures (1,2,3,4) show species histograms comparing flowering dates (Julian dates) of herbaria and Chinnor data sets [8]. The result of the two-sample s equal variances t –test, created a comparison between flowering dates of Reading university herbarium and Chinnor herbarium of the selected *Festuca* species: *F. arundinacea*, *F. gigantea*, *F. pratensis*, and *F. rubra* (Tables 3,4,5,6). The total results of all t- test analysis except for *F. rubra* presented significant p- values (<0.05)[9]. Therefore, the alternative hypothesis that herbaria flowering dates and Chinnor dates are significantly differentiated can be accepted and rejected the null hypothesis for the species; *F. arundinacea*, *F. gigantea*, and *F. pratensis*. In contrast, the null hypothesis that there is no significant difference between herbaria and Chinnor flowering dates can be accepted for *F. rubra [10]*.

Table 3. Result of t- test comparing flowering dates of F. arundinacea from Reading university herbarium, and Chinnor, presenting the number of observations (n), mean, standard deviation and significance level (P-value).

	Sample size (n)	Mean	Stander deviation	P-value
Reading university herbarium	5	205	31.07	0.0007
Chinnor herbarium	5	127.4	8.70	

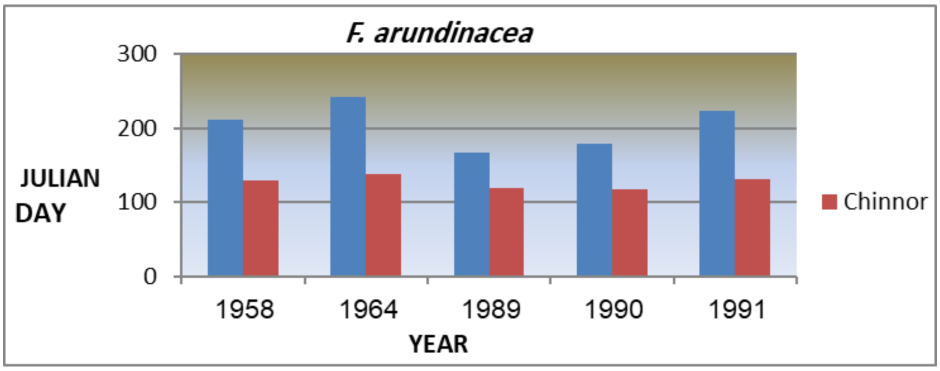

Figure 1. Graph comparing Reading university herbarium and Chinnor flowering dates of F. arundinaceae

Table 4. Result of t- test comparing flowering dates of F. gigantea from Reading university herbarium and Chinnor, presenting the number of observations (n), mean, standard deviation and significance level (P-value).

	Sample size (n)	Mean	Stander deviation	P-value
Herbaria	3	227	18.2	0.08
Chinnor	3	200.7	8.08	

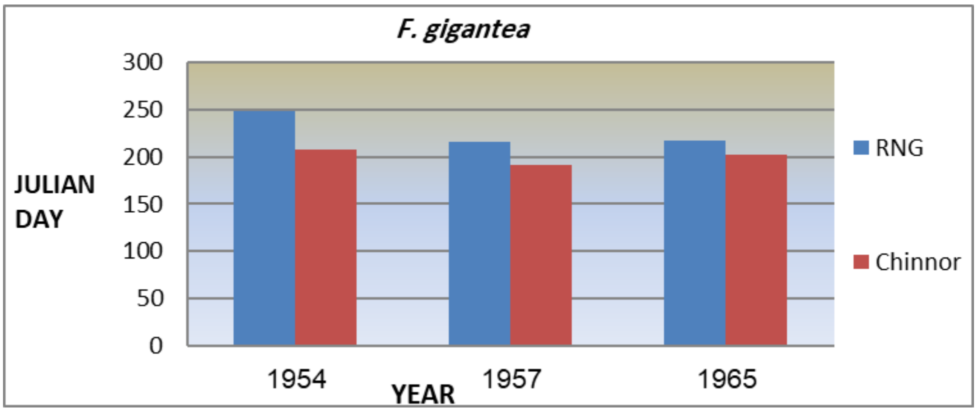

figure 2. Graph comparing Reading university herbarium and Chinnor flowering dates of F. gigantean

Table 5. Result of t- test comparing flowering dates of F. pratensis from Reading university herbarium and Chinnor, presenting the number of observations (n), mean, standard deviation and significance level (P-value).

	Sample size (n)	**Mean**	**Stander deviation**	**P-value**
Herbaria	9	171.5	30.06	0.01
Chinnor	9	200.8	11.08	

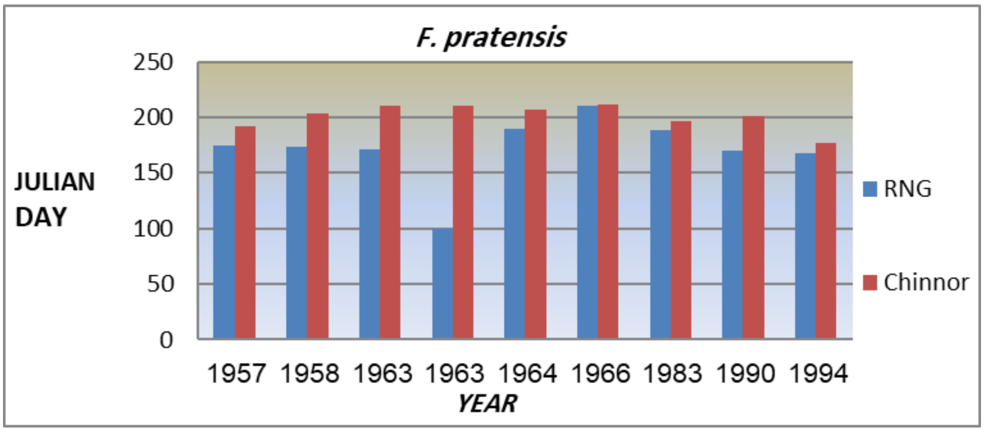

Figure 3. Graph comparing Reading university herbarium and Chinnor flowering dates of F. pratensis.

Table 6. Result of t- test comparing flowering dates of F. rubra from Reading university herbarium and Chinnor, presenting the number of observations (n), mean, standard deviation and significance level (P-value).

	Sample size (n)	Mean	Stander deviation	P-value
Herbaria	16	170.9	18.9	2.02E-09

	Sample size (n)	Mean	Stander deviation	P-value
Chinnor	16	125.6	10.05	

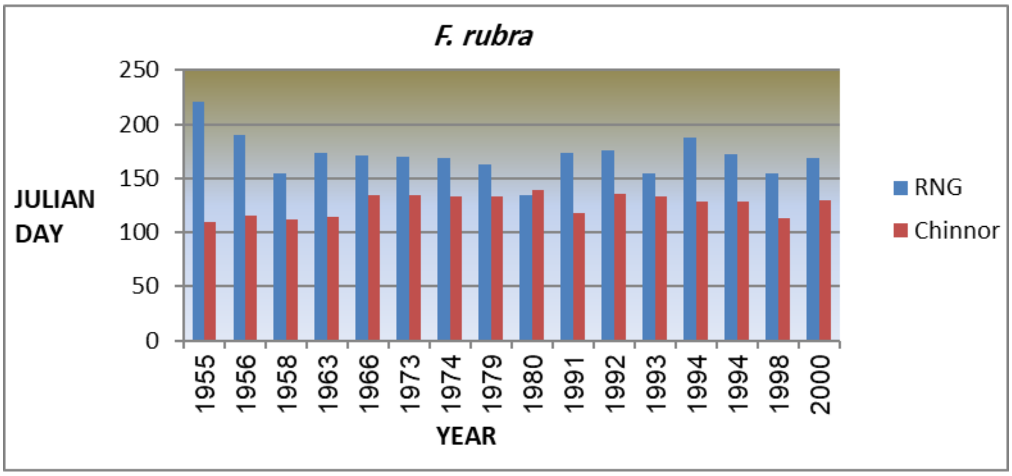

Figure 4. *Graph comparing Reading university herbarium and Chinnor flowering dates of F. rubra*

Discussion

Comparing herbarium datasets of Festuca species with specific locality data, such as the Chinnor data set in the British Isles, highlights differences in temporal span and habitat coverage [11]. Herbaria often span centuries, documenting historical range expansions, while modern, localized datasets like Chinnor provide intensive, recent, and precise ecological data [12],[13]. Findings were confirmed by comparing herbaria and Chinnor data sets for specific years. herbarium data can be sporadic in space and time. Local datasets are often intensive, offering a high-resolution, dense grid of sightings within a specific area, capturing micro-habitat preferences better [14],[15]. Integrating the two allows researchers to track long-term environmental change, such as changes in *Festuca* flowering times due to climate change, or identifying the introduction and spread of invasive Festuca species in the British Isles [16].

The flowering response of five *Festuca* species has been revealed in negative results (negative slopes) [17], except for *F. rubra* which produced a positive slope. This result corresponds partially to flowering dates which have been demonstrated in a recent study by Fitter & Fitter. Findings that *F. arundinacea* flowered - 0.4 days early per year, and *F. pratensis* -0.6 days early agree with the Fitter & Fitter, which found that these species were flowered -0.3, and -0.5 days early per year respectively. However, the result of *F. rubra* which found -0.0006 days early per year, disagrees with Fitter & Fitter, which showed +0.2 days per year later. In the case of *F. gigantea*, the current study could not conduct the first flowering trend of this species to be compared with Chinnor data sets, due to the insufficient collected specimens.

Further significant differences between the two data sets were conducted by P-value test. *F. arundinacea*, and *F. pratensis* showed significant P-value with 0.0007, and 0.01 respectively. However, these results do not correspond to the considerable similarities that have been found in the flowering advancement of these two species within the two data sets. In contrast, *F. rubra* showed a negligible P-value, which does not reflect the variation found between the two data sets.

There are explained reasons for conducting such opposing results; firstly, Fitter & Fitter, first flowering stages (FFSs) were collected within a specific small area (Chinnor) in UK. On the other hand, in this study the species were collected from a wide range of areas of the British Isles.

Conclusion

This study evaluated the usefulness of herbarium specimens for investigating long-term flowering phenology in four *Festuca* species by comparing flowering dates from the Reading University Herbarium (RNG) with the Chinnor dataset. The results demonstrate that herbarium collections can provide valuable historical phenological information, although their reliability may differ among species. Significant differences between the two datasets were identified for *F. arundinacea*, *F. gigantea*, and *F. pratensis*, whereas *F. rubra* showed a different statistical pattern. These findings indicate that herbarium-derived flowering dates should be interpreted carefully when they are used as representatives of flowering patterns across broader geographic areas. The comparison also highlights the importance of combining herbarium collections with systematic field observations. Herbarium specimens provide access to historical records collected over extended periods, while localized datasets such as Chinnor can provide more consistent and detailed observations from a specific area. Therefore, integrating these complementary sources may improve the assessment of long-term changes in plant phenology and help investigate possible responses to climate change. However, the study was limited by gaps in herbarium collections and the relatively small number of comparable specimens for some species, particularly *F. gigantea*. In addition, differences in geographic coverage between the RNG and Chinnor datasets may contribute to variation in flowering dates. Consequently, herbarium data should not be considered a direct substitute for standardized field observations. Nevertheless, the findings support the potential of herbarium collections as an important source of historical phenological evidence and demonstrate their value for further research into flowering-time changes in *Festuca* and other grass species.

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