What are the predominant pests and diseases afflicting gardens in the UK?

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Declaration of Interests

The authors declare no competing interests

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ABSTRACT

Gardening is a major pursuit in the UK, providing health and wellbeing benefits to individual gardeners, while providing important habitats for wildlife and supporting ecosystem services such as pollination. However, garden plants are afflicted by an array of pests and diseases, but until now, their importance has not been quantified, but only inferred from other sources. Here, we describe the results of a nationwide survey in the UK, designed to assess which pests and diseases gardeners consider the most important, and whether these vary across regions of the country. We found that slugs and snails and various aphids are considered the most important pests, while late blight and rose black spot are the most important diseases. Most importantly, we concluded that inferences drawn from rankings of pest and disease incidence based on enquiry data should not be taken as a proxy for importance. Many pests and diseases varied in their importance across the country and in most cases there was good agreement between regional values and current national distribution maps, suggesting that the survey produced reliable data, without regional bias.

*Keywords:* fungi, insects, introduced species, molluscs, surveys

**1. Introduction**

There are approximately 27 million gardeners in the UK tending to more than 22 million gardens (Loram et al., 2007). Furthermore, it is estimated that 19-27% of the land area in UK cities supports gardens, underlining their importance in the urban landscape (Loram et al., 2007). In economic terms, ornamental horticulture, landscaping and tourism contribute more than £24 billion annually to UK GDP and supported 568,700 jobs in 2017 (Anon, 2018a). In 2017, the UK domestic garden products market was estimated to be worth £4.9 billion (Appleby, 2018) and possession of, or proximity to a garden significantly increases the value of a property (Gibbons et al., 2014). Gardening as a pursuit has long been known to benefit human health and wellbeing (Cameron et al., 2012) and significantly improves children’s connection to nature (Hand et al., 2017). This is particularly important as the majority of people now live in urban environments, which are heavily depleted in biodiversity (Miller, 2005).

The flora of domestic gardens is diverse and it has been estimated that as many as 400,000 plant varieties exist in UK gardens (Royal Horticultural Society, 2015). Plant diversity within gardens is high, and remarkably uniform across the UK (Loram et al., 2008), with a preponderance of non-native species. However, this high diversity and native/alien mixture brings many benefits for plant-associated invertebrates, providing habitats and food for rare species and those of ecological importance, such as pollinators and associated invertebrates (Salisbury et al., 2015, 2017, 2020). Furthermore, in a study of Swiss gardens, ecologically-inclined management techniques, including greatly-reduced use or absence of pesticides and fertilisers not only benefited biodiversity, but also people’s wellbeing and aesthetic enjoyment of gardens (Lindemann-Matthies and Marty, 2013).

The diversity of garden plants is also mirrored by the large range of pests and diseases found infesting or infecting them. Although there is much known about the identity and biology of UK garden pests and diseases (Greenwood and Halstead, 2018), no studies have considered which pests and diseases are most important, in contrast with agricultural crops. This stems from the facts that most gardens have restricted access and are largely unregulated habitats, in which management decisions are determined by the knowledge of the individual owners (Lin et al., 2017). Indeed, studies of garden pests and diseases are usually focused on the introduction of alien species, particularly if these become invasive (Smith et al., 2006).

A knowledge of, and ranking for, the most important pests and diseases affecting UK gardens is required to prioritise activities such as research and knowledge transfer, to inform policy makers and to ensure gardens provide the maximum benefits aesthetically, socially and for the environment. In this respect, the gardeners themselves represent a huge potential source of information, which can be accessed via surveys and other similar citizen science projects (e.g. Cooper et al., 2007; Loram et al., 2011). The use of such data is critical, because unlike commercial systems, gardeners are likely to consider non-economic and qualitative factors when rating the importance of pests and diseases such as their impact on the aesthetics (e.g. the appearance of flowers or the finish of a lawn).

A good example of the use of citizen science surveys is provided by the triennial ‘Pesticide User Habits Survey’, published by the UK Health and Safety Executive, and last performed in 2016 (Anon, 2018b). A sample of 495 gardeners across the UK revealed a variety of pesticides being applied, with molluscicides most common, being used by 68% of respondents. Meanwhile, 53% used insecticides and 32% used fungicides, suggesting that pest and disease problems are widespread across UK gardens. These data may indicate that slugs and snails could be regarded as the most important pests, and that insect pests are of more concern than plant diseases. However, it could also represent availability and/or cost of chemicals or be a function of the level of damage perceived or the knowledge of gardeners. Interestingly, this survey also found that molluscicides had been commonly, but consistently, used over the previous nine years, but use of insecticides and fungicides had increased considerably over this time (Anon, 2018b). Taken together these data suggest that an assessment of pest and disease importance in UK gardens, using information from gardeners is urgently required.

The Royal Horticultural Society (RHS) is the only organisation undertaking surveillance for pests and diseases in UK gardens, primarily through the gardening advice service (<https://www.rhs.org.uk/membership/rhs-gardening-advice>) used by its 525, 000 members. Each year, this service deals with over 100,000 enquiries, of which c. 10,000 relate to pest and disease problems, clearly demonstrating the concern of gardeners and the need for research to better understand these problems. From these enquiries, the RHS publishes a list of the most common enquiries annually (e.g. <https://www.rhs.org.uk/science/articles/2018-pests-and-diseases>). Although the media has interpreted this as a proxy for a ranked list of the most important pests and diseases in UK gardens, such an interpretation may not be accurate. For example, enquiries are only received from RHS members (who may not be representative of UK gardeners, geographically or socio-economically) and are more likely to concern perennial plants than annual species. Furthermore, enquiries may concern identification and/or control advice and therefore pests and diseases which are easy to identify may be underrepresented in RHS enquiries and *vice versa*. This can easily lead to the problem seen in many citizen science databases in which records of species are severely biased, and more a reflection of recorder knowledge than actual biology (Ward, 2014; Mair and Ruete, 2016). Citizen science data can also be biased towards rare records with common items being under-recorded. The RHS also publishes information on its website on the pests and diseases commonly encountered in gardens; this information is freely available and the most popular profiles are accessed more than 100,000 times annually. However, the frequency with which records are accessed are also likely to be biased, due to the same problems of users’ identification ability, but also because such web site ‘hits’ are not limited to UK residents.

To address the aforementioned gaps in our knowledge, this study aimed to determine which are the most important pests and diseases afflicting UK gardens, using a citizen science approach. We conducted an independent nationwide survey of gardeners and compared the ranking of pests and diseases from this with those obtained from the enquiries database (hereafter termed ‘enquiries’) and the website hits (hereafter termed ‘web hits’). Our hypothesis was that the two latter data sets would be biased, and that the survey would provide a quantified assessment of UK gardeners’ perceptions of pest and disease importance. We further hypothesised that variations in climate across the UK would affect the types of plants grown and thus certain pests and diseases would vary in their perceived importance from one area to another.

**2. Materials and Methods**

A national survey was performed to assess what gardeners across the UK perceived to be the most important pests and diseases in their own garden or allotment, rather than ones that they had seen or visited. The survey was undertaken from 3 February to 30 June 2017 and was promoted through print, social media, email and radio. For example it was featured in the RHS members’ magazine “The Garden”, on local radio (e.g. interview on BBC Surrey) and was promoted by posts on Instagram, Facebook, Twitter and WordPress (<https://thegardensurvey.wordpress.com/>). Prior to completing the survey all participants were informed that the anonymised data would be used for research.

*2.1 Survey of gardeners*

The survey was undertaken using the online platform SurveyMonkey (<https://www.surveymonkey.com/>). A quantitative approach was used for the majority of the survey to enable statistical analysis of the data. Participants were required to answer based on experiences in their own gardens, and to state the county in which they gardened, to reduce influences based on information from other sources such as the media or places they had visited. The survey could only be completed once for each IP address, decreasing the likelihood that it was completed multiple times by participants.

The RHS website includes advice profiles ranging from how to grow certain plants, to designing a garden, to plant health. Of these, 338 advisory profiles discuss the pests and diseases commonly encountered in gardens and those which are increasing in importance (<https://www.rhs.org.uk/advice/plant-problems>). The plant pests and diseases that appeared in a list of the 500 most viewed advice profiles were selected for inclusion in the rating section of the survey. The subject of each of these profiles was categorised into groups which gardeners would recognise. For example, ‘rusts’ or ‘cankers’ were included as broad categories in the disease section, since gardeners are likely to be better at identifying these symptoms than identifying the aetiology or the individual causative agents.

Participants were first provided with a standardised definition of what was meant by ‘most important’ pests and diseases; which was repeated throughout the survey: *In this case, how much of a nuisance you find the pest or disease. This could be defined as a reduced yield, a decrease in aesthetic value (how the plant looks), or any other negative consequence resulting from an interaction between the pest/disease and the plant*. This definition represents the gardeners’ perception of the problems caused by a pest or disease (as influenced by a range of factors such as their cultural perceptions, knowledge of the damage caused by particular pests and diseases, value of the affected plant etc.) and should not be interpreted as an indicator of abundance.

We selected the top 36 pests and 30 diseases for inclusion, defined by their number of views in the advisory profiles. Those pests and diseases omitted were for profiles that were infrequently accessed. We deliberately grouped some species together (e.g. ‘slugs and snails’), as most home gardeners would not be able to identify different species, and the damage and control methods are broadly the same, irrespective of species identity. Each species or group was illustrated by a colour photograph with a request to rate the pest and disease in their own garden from 1 (low) to 5 (high), based on how ‘important’ they perceived it. The rating section of the survey was designed so that the pests and diseases appeared in a random order to minimise tiredness effects and order bias (Cohen et al., 2000). Each pest and disease was accompanied by the common and Latin names, the plant types affected, a brief description of the damage caused, and any unique features that would help in identification. Finally, there was an opportunity for participants to leave additional comments at the end of the survey to allow the collection of more qualitative supplementary information, to help in interpretation of the data.

Location data from participants were grouped into 12 regions, based on The Nomenclature of Territorial Units for Statistics (NUTS1) geocode standard of the UK developed by the European Union for statistical purposes (available at <https://www.revolvy.com/page/NUTS-1-statistical-regions-of-England>).

*2.2 Calculating minimum survey sample size*

With the population of the UK estimated to be 65,648,100 people in the middle of 2017 (Office for National Statistics, <https://www.ons.gov.uk/>), a large sample size was required to be confident that the responses of the survey participants were representative. The margin of error and sample size were calculated using the SurveyMonkey software to determine how many participants were needed to be confident that the perceptions of the population were represented in the survey results. The margin of error was used to calculate the minimum sample size required to represent the perceptions of the UK population. The recommended sample size for a population of 65,648,100 at a confidence level of 99% and a margin of error of 3% is 1,849 which the survey surpassed with a sample size of 1,870.

*2.3 RHS Gardening Advice service and web hits*

The RHS provided data on the 500 most-viewed advisory profiles on its website in 2016. These data were ranked by the number of unique hits for each pest and disease profile and were used to derive the number of web hits for the specific plant pests and diseases included in this survey. Data for horse chestnut leaf miner, rosy apple aphid, glasshouse thrips, rose leaf rolling sawfly, tortrix moth caterpillar, berberis sawfly and alder leaf beetle were missing from the web hit data set, as there were either no specific pages in existence for these insects or they fell outside of the 500 most viewed web pages. Data for Dutch elm disease, ash dieback, downy mildews, galls and snow mould were missing from the fungal list for the same reasons.

The RHS also provided data on the enquiries received through its RHS Gardening Advice service in 2016 on plant pests and diseases. These were summed to produce the total number of enquiries received through e-mail, telephone and by post.

Data for RHS enquiries and web hits from 2016 was chosen as it matched most closely in time to when the survey was done.

*2.4 Statistical analysis*

Associations between mean importance scores from the survey and for total number of RHS enquiries and web site hits were examined with Pearson correlation in R 3.6.1.

Kruskal-Wallis one-way ANOVA was used to test for significant pairwise differences in the mean ranking of importance of each pest and disease across the UK regions. Means were separated with the Dunn test, employing a Bonferroni correction factor with package ‘dunn.test’ in R 3.6.1.

**3. Results**

*3.1 The most important pests*

The ranked order of importance (from the survey, enquiries and web hits) for all pests is given in Table 1. Slugs and snails were considered the most important pests, and the high value of the mean importance score indicates that the vast majority of responders described their importance as ‘high’ (with a maximum score of 5). However, a notable feature of these data is the lack of congruence between them. Indeed, no significant association was found either between survey and enquiry data (r = 0.194, P > 0.05), or between enquiry and web hit data (r = 0.077, P > 0.05) (Fig. 1). There was a weak correlation between survey and web hit data (r = 0.444, P = 0.03) (Fig. 1B). As can be seen in Table 1, the top five pests in the survey also ranked within the top 10 in enquiry data. However, some notable anomalies were carrot fly (*Psila rosae*), ranked 6th in the survey, but 33rd in the enquiry data, and box moth (*Cydalima perspectalis*), which was top in the enquiry table, but ranked only 29th in the survey. A similar situation for carrot fly occurred with web hit data where it was ranked 27th, but not with box moth which was similar to the survey, with a rank of 22nd.

*3.2 The most important diseases*

Respondents considered late blight (caused by *Phytophthora infestans*) of solanaceous crops to be the most important disease (Table 2). However, honey fungus (*Armillaria* spp*.*, most commonly *A. mellea*) was top of the enquiries list and black spot of roses (*Diplocarpon rosae*) was top of the web hits list. The latter was ranked second in the survey, but honey fungus came only 14th in this list. Furthermore, late blight and rose black spot, were only ranked 19th and 22nd respectively in the enquiries list, showing that using the enquiries data as an indication of disease importance would give a very misleading impression. This was exemplified by the fact that, as with pests, there was no association between survey and enquiry data (r = 0.148, P > 0.05) (Fig. 2A). However, there was a positive association between survey and web hit data (r = 0.608, P < 0.01) and a weak association between enquiry and web hit data (r = 0.430, P = 0.035) (Fig. 2C).

*3.3 Regional differences in pest importance*

Eleven of the 36 pests in the survey showed a difference in their perceived importance across the 12 regions (Table 3). Three notable examples are given in Fig. 3, while the remaining 33 distributions are presented in Supplementary information (Fig. S1). Slugs and snails showed a uniform pattern across the country and were perceived to be equally important in all areas (Fig. 3A). However, lily beetle (*Lilioceris lilii*) showed a lower importance score in Northern Ireland, Scotland and Wales (Fig. 3B). Meanwhile, although the ANOVA failed to detect a difference between areas for box tree moth, the means separation test suggested that this insect produced a lower importance score in Northern Ireland and Scotland (Fig. 3C). Perhaps of most concern is the fact that respondents reported that the recently-introduced box tree moth occurred in their garden in all 12 areas of the country, suggesting that the insect is much more widely distributed than is currently thought, or that misidentification had occurred.

It is noteworthy that eight of the 11 species (or groups of species) that showed a difference in nationwide patterns occurred in the top 15 of the survey. This consistency suggests that the differences are real. Groups that showed notable differences in distribution across the UK include blackfly (mostly bean aphid, *Aphis fabae*), which was considerably more important in the southern areas, and cabbage caterpillars (*Pieris brassicae* and *P. rapae*) which were most important in the south west and Midlands (Fig. S1C). Interestingly, there was a reasonable agreement in the importance of *C. perspectalis* and the cabbage butterflies (Fig. 3C, S1C), reinforcing the suggestion of misidentification, since the larvae of the moth resemble that of *P. brassicae* (although the two species have very different host plants)*.* Other species to show notable differences were carrot fly (Fig. S1E), which was more important in the east of England and Allium leaf miner (*Phytomyza gymnostoma*) which was most important in the southern half of the country (Fig. S1L).

*3.4 Regional differences in disease importance*

In contrast to the pests, only four of the 30 diseases showed a difference in importance across the country (Table 4). Late blight was not one of these and was considered uniformly problematic across all regions (Fig. 4A), underlining its status as the most important disease (Table 2). Two diseases that showed notable differences were rose black spot which was less important in Scotland and Northern Ireland (Fig. 4B) and club root of brassicas (*Plasmodiophora brassicae*), which tended to be more important in the Midlands and northern parts of the Great Britain (Fig. 4C). The distributions for the remaining 27 diseases are presented in Fig. S2.

**4. Discussion**

From our survey, slugs and snails are considered the most important pests across the UK, while late blight is the most important disease. We found that there was poor agreement between the results of the survey and the ranked lists arising from RHS enquiries, indicating that using the latter as an indication of pest or disease importance would present a misleading impression of gardeners’ perceptions. There was a correlation between the survey results and the ranked lists from RHS web hits, although this relationship was stronger for the disease than pest lists. Our original hypothesis was therefore partly upheld and we recommend using the results of this survey in conjunction with the data generated from the enquiry and web hit lists to indicate the importance of pests and diseases in UK gardens. It is not possible to survey gardeners frequently therefore we propose using the survey as a baseline which can be supplemented by analysing the number of web hits on advisory profiles. Analysis of the enquiry data would provide an indication of pests and diseases that are changing in importance, e.g. the increased perception of importance of box tree moth as it becomes established in the UK. Our second hypothesis was that certain pests and diseases would vary in importance across the country and this was also upheld, in that some species showed notable geographic differences. Variations in climate are likely to affect the types of plants grown and thus the habitats available to different pests and diseases. Moreover, pests and diseases will have their own climatic requirements, and for invasive species, their distribution will be influenced by their site of introduction and pathways of dissemination. The distribution data are important, not just for understanding regional distributions, but also for determining if some level of bias existed in the survey data.

The prevalence of slugs and snails is notable and is likely related to the fact that these invertebrates have a broad range of diets, including dead and living plant material. Furthermore, the fact that our category was broad, encompassing all mollusc species, means that any underlying species’ preferences for factors such as climate, soil types, etc. would not be obvious The problems caused by slugs and snails are likely to be seen across the country, since these pests were equally troublesome across all 12 geographical areas. The latter point also suggests that the results of the survey were not influenced by gardeners having different opinions in certain areas, but perhaps instead by the nature of flowers or vegetables grown. Coupled with the known uniformity of vegetation in gardens across the country (Loram et al., 2008), this is good evidence for a lack of bias in the survey results.

The second most important pest category was ‘aphids’, many of which were likely to be records of the green peach-potato aphid, *Myzus persicae* (from the supplementary comments provided), but also species such as the rose aphid (*Macrosiphum rosae*), while third was ‘blackfly’ (*A. fabae*). Although there are still some pesticides sold for UK gardeners to combat these pests, their use is becoming more restricted. More broadly, issues with insecticide resistance have risen dramatically in recent years (Bass et al., 2014, 2015). Virus transmission by aphids is an important aspect of their pest status, but plant viruses only ranked 15th in the survey list. This disparity in perceived importance of viruses and their vectors may represent a lack of understanding of this aspect of aphid biology (and the biology of other vectors such as nematodes and thrips) by the respondents.

Several other insect pests varied in prevalence across the country and provide good evidence for the lack of bias in the survey data. Lily beetle was considered to be much less important in Northern Ireland, Scotland and Wales, which is very much in agreement with the recorded distribution of this insect in 2016 (<https://www.rhs.org.uk/advice/profile?pid=553>). Rosemary leaf beetle (Chrysolina americana) (Fig. S1U) was considered much more important in London, south east and south west England, again showing excellent agreement with the 2016 distribution (<https://www.rhs.org.uk/advice/profile?pid=555>). Meanwhile carrot fly (Fig. S1E) was much more important in eastern England, coinciding with the main area of production, on the lighter sandy soils (<http://britishcarrots.co.uk/carrot-production-facts/>) and Allium leaf miner was most prevalent in southern England (Fig. S1L), again coinciding with the main area of onion production (<http://britishonions.co.uk/faqs/>).

Conversely, three pests primarily of glasshouse plants, whitefly (*Trialeurodes vaporariorum*), red spider mite (*Tetranychus urticae*) and glasshouse thrips (*Heliothrips haemorrhoidalis*) all showed no differences in importance across the country. This is most encouraging, as one would expect relatively little variation in crop type or conditions within domestic glasshouses. The fact that respondents were making similar decisions about the importance of these pests across the country reinforces the suggestion that our survey is relatively unbiased by the geographic location of respondents.

One species of insect, the box tree moth, produced a nationwide pattern that was completely different from the current distribution (<https://www.rhs.org.uk/advice/profile?PID=760>). Adults of this species were first reported in the south east England UK in 2008 and larvae were first found in private gardens in 2011 (Salisbury et al., 2012). Although there are a few records from northern England and Scotland, it is still a southern insect in the UK. Our survey suggested that, while it was less important in Northern Ireland and Scotland, it occurred throughout the country. If this were true, it suggests a considerable expansion in the distribution of this pest. However, despite providing respondents with a detailed text description (e.g. that the larvae only eat leaves of box, *Buxus sempervirens*) and a photograph of the larvae, it is likely that some respondents mistook larvae of large white butterflies (*P. brassicae*) for those of this species. This phenomenon has been observed previously where increased awareness of box tree moth in 2016 led to a simultaneous increase in reports of caterpillars of both box tree moth and large white butterfly (<https://www.rhs.org.uk/advice/advice-blogs/help-and-advice/March-2017/2016-pest-disease-top-10>). Furthermore, the fact that 31% of pests varied in importance across the UK, while only 13% of diseases did so probably also represents the fact that the pest data are more reliable, possibly because respondents were in general more able to identify the pests than the diseases.

Late blight was the most important disease across the UK and showed no difference in its prevalence from one region to another. The second most important disease was rose black spot; late blight and rose black spot were ranked 19th and 22nd respectively in the enquiries list. This discrepancy may be because gardeners are familiar with these diseases and therefore do not submit enquiries about them. This conjecture is supported by the most recent published list of RHS enquiries in which rose black spot is listed eighth (<https://www.rhs.org.uk/science/articles/2019-pests-and-diseases>); membership of the RHS has continued to increase any may represent less experienced gardeners who are not so familiar with common diseases. There has been no concomitant increase in late blight enquiries, possibly because gardeners choose not to grow susceptible crops. Honey fungus was suggested to be the most important disease, based on enquiries, but our survey shows that this may not be the case; this fungus only came 12th in the survey. This fungus may have been perceived to be less important in the survey as gardeners are more familiar with the honey-coloured toadstools which appear in autumn (outside the survey period) than the more characteristic white fungal mycelium growing beneath the bark.

Two diseases that showed differences in importance between regions were rose black spot and club root. There is no obvious reason why rose black spot importance should vary across the country since there is little varietal resistance to the disease (and no evidence for different varieties being grown nationally) and roses are grown throughout the UK. Meanwhile club root tended to be more important in the more northern areas of the country, perhaps because soils in that area tend to be more acidic (<http://www.landis.org.uk/soilscapes/>), favouring development of the disease (Dixon, 2014). One important emerging disease is box blight (causative organisms *Calonectria pseudonaviculata* and *C. henricotiae,* LeBlanc et al. (2018)). This was considered much less important by survey respondents, compared with enquiry and web hit data, and again may reflect the lack of mycological knowledge of home gardeners. However, the remarkable congruence between our geographic distribution patterns of the two species (Figs. 3C and S2L) also suggests confusion between the two, since ‘window feeding’ damage by young box tree moth larvae can superficially resemble that caused by the fungi (LeBlanc et al., 2018; Plant et al., 2019).

The results of our survey are important, as they will inform management decisions in gardens that can impact upon biodiversity at the national scale. Information to support such decisions is rare (Cook et al., 2012), but citizen science surveys can provide a powerful tool for the acquisition of data on the ecosystem services provided by gardens (Deguines et al., 2012). An excellent example of a survey similar to the one conducted here is that of Muratet and Fontaine (2015), who used a citizen science approach to examine the effects of garden pesticide use on pollinating insects in France. Perhaps not surprisingly, insecticide use had a negative effect on pollinators, but fungicide and molluscicide use had a positive effect on butterfly and bumblebee abundance. This was attributed to higher plant species diversity in gardens when diseases and/or molluscs were controlled. Regulations around pesticide use, especially in domestic situations, are being reviewed in Europe, e.g. amateur gardeners can no longer purchase or use pesticides (Brun, 2019). Thus, our findings that slugs and snails and late blight are the most important pests and diseases and that the pesticides used to control them may be lost could have far-reaching implications for beneficial insects in UK gardens. Future surveys could be used to record the use of pesticides and link these to changes in the distributions of beneficial organisms and injurious pests and diseases, thereby enabling gardens to fulfil their potential as providers of ecosystem services, while maintaining the socio-economic needs of their owners (Aronson et al., 2017). Further research should also be considered to investigate differences in the perception of the importance of different pests and diseases between different segments of the population, e.g. age or “rural” versus “urban” populations.

**5. Conclusions**

We have produced the first survey-based list of the most important pests and diseases afflicting UK gardens. These lists bear limited similarity to those inferred from numbers of enquiries to experts or web site hits. We recommend using the results of this survey in conjunction with the data generated from the enquiry and web hit lists to indicate the importance of pests and diseases in UK gardens. Slugs and snails and various aphid species are the most important pests, while late blight, rose black spot and various powdery mildews were the top three most important diseases. Our survey showed good general agreement in geographical distributions of pest importance across the country with known national distributions, suggesting that the survey was little affected by bias. These data will be important for informing management practices in gardens, and the use of these areas for biodiversity, in the face of future reduced pesticide inputs.

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**Figure legends**

**Fig. 1.** Scatter plot of importance score of pests from three different data sources. A: mean score in the questionnaire survey v. number of enquiries in the RHS list; B: mean score in the questionnaire survey v. number of RHS web site hits and C: number of RHS enquiries v. number of RHS web site hits. Please note, logarithms have been used to depict enquiry number and web hits, to aid clarity.

**Fig. 2.** Scatter plot of importance score of diseases from three different data sources. A: mean score in the questionnaire survey v. number of enquiries in the RHS list; B: mean score in the questionnaire survey v. number of RHS web site hits and C: number of RHS enquiries v. number of RHS web site hits. Please note, logarithms have been used to depict enquiry number and web hits, to aid clarity.

**Fig. 3**. Mean (± one standard error) importance value for slugs and snails (A), lily beetle (B) and box tree moth (C) across geographic regions of the UK. Key to x axis: GL: Greater London, SE: south east England; SW: south west England, WM: west Midlands; EM: east Midlands; EE: eastern England, NW: north west England; NE: north east England; YH: Yorkshire and Humberside; NI: Northern Ireland; SC: Scotland and W: Wales.

**Fig. 4.** Mean (± one standard error) importance value for late blight (A), rose black spot (B) and clubroot disease (C) across geographic regions of the UK. Key to x axis as in Fig. 3.

Fig. 1



Fig. 2



Fig. 3



Fig. 4



**Table 1.** Ranking of the most important insect pests afflicting UK gardens. ‘Score’ represents the mean importance score (maximum 5) given by survey respondents. Also tabulated is the ranked order of pests from RHS enquiry data and web hits.

|  |  |  |  |
| --- | --- | --- | --- |
| Order by survey | Score | Order by enquiries | Order by web hits |
| Slugs & snails | 4.384 | Box tree moth | Slugs & snails |
| Aphids | 3.639 | Aphids | Vine weevil |
| Blackfly | 3.411 | Slugs & snails | Allium leaf miner |
| Cabbage caterpillars | 3.302 | Blackfly | Aphids |
| Vine weevil | 3.259 | Cabbage caterpillars | Leatherjackets |
| Carrot fly | 3.168 | Vine weevil | Chafer grubs |
| Lily beetle | 2.972 | Cushion scale | Lily beetle |
| Glasshouse whitefly | 2.775 | Lily beetle | Chrysanthemum leaf miner |
| Codling moth | 2.684 | Rosemary beetle | Soft scale |
| Cabbage root fly | 2.488 | Fuchsia gall mite | Cushion scale |
| Horse chestnut leaf miner | 2.464 | Woolly aphid | Rabbits |
| Glasshouse red spider mite | 2.462 | Berberis sawfly | Woolly aphid |
| Mealybug | 2.439 | Chafer grubs | Blackfly |
| Allium leaf miner | 2.409 | Viburnum beetle | Cypress aphid |
| Woolly aphid | 2.329 | Rosy apple aphid | Mealybug |
| Chafer grubs | 2.301 | Mice & voles | Rosemary beetle |
| Leatherjackets | 2.272 | Soft scale | Cabbage root fly |
| Soft scale | 2.253 | Tortrix moth caterpillar | Cabbage caterpillars |
| Cherry blackfly | 2.216 | Alder leaf beetle | Moles |
| Mice & voles | 2.212 | Agapanthus gall midge | Viburnum beetle |
| Rosy apple aphid | 2.170 | Glasshouse red spider mite | Glasshouse red spider mite |
| Viburnum beetle | 2.160 | Mealybug | Box tree moth |
| Rosemary beetle | 2.153 | Codling moth | Codling moth |
| Glasshouse thrips | 2.133 | Allium leaf miner | Mice & voles |
| Rose leaf rolling sawfly | 2.110 | Cherry blackfly | Glasshouse whitefly |
| Rabbits | 2.106 | Glasshouse thrips | Cherry blackfly |
| Tortrix moth caterpillar | 2.089 | Glasshouse whitefly | Carrot fly |
| Berberis sawfly | 2.057 | Cypress aphid | Agapanthus gall midge |
| Box tree moth | 2.047 | Leatherjackets | Fuchsia gall mite |
| Moles | 2.009 | Moles |  |
| Cushion scale | 1.942 | Rabbits |  |
| Cypress aphid | 1.884 | Horse chestnut leaf miner |  |
| Chrysanthemum leaf miner | 1.845 | Carrot fly |  |
| Fuchsia gall mite | 1.832 | Cabbage root fly |  |
| Agapanthus gall midge | 1.760 | Rose leaf rolling sawfly |  |
| Alder leaf beetle | 1.620 | Chrysanthemum leaf miner |  |

Species identities:

Slugs and snails: a variety of species, mostly the snail *Cornu aspersum* and slugs in the genera *Arion, Deroceras* and *Tandonia*; Aphids: mostly green peach aphid, *Myzus persicae*; Blackfly: mostly black bean aphid, *Aphis fabae*; Cabbage caterpillars: *Pieris brassicae* and *P. rapae*; Vine weevil: *Otiorhynchus sulcatus*; Carrot fly: *Psila rosae*; Lily beetle: *Lilioceris lilii*; Glasshouse whitefly: *Trialeurodes vaporariorum*; Codling moth: *Cydia pomonella*; Cabbage root fly: *Delia radicum*; Horse chestnut leaf miner: *Cameraria ohridella*; Glasshouse red spider mite: *Tetranychus urticae*; Mealybug: *Planococcus* spp.; Allium leaf miner: *Phytomyza gymnostoma*; Woolly aphid: *Eriosoma lanigerum*; Chafer grubs: *Hoplia*, *Melolontha* and *Phyllopertha* spp.; Leatherjackets: *Tipula* spp.; Soft scale: *Coccus hesperidum;* Cherry blackfly: *Myzus cerasi*; Mice and voles: *Apodemus* spp., *Mus* spp. and *Microtus* spp.; Rosy apple aphid: *Dysaphis plantaginea*; Viburnum beetle: *Pyrrhalta viburni*; Rosemary beetle: *Chrysolina americana*; Glasshouse thrips: *Heliothrips haemorrhoidalis*; Rose leaf-rolling sawfly: *Blennocampa phyllocolpa*; Rabbits: *Oryctolagus cuniculus*; Tortrix moth: *Archips podana*; Berberis sawfly: *Arge berberidis*; Box tree moth: *Cydalima perspectalis*; Moles: *Talpa europaea*; Cushion scale: Pulvinaria floccifera; Cypress aphid: Cinara cupressivora; Chrysanthemum leaf miner: Chromatomyia(Phytomyza) syngenesiae; Fuchsia gall mite: Aculops fuchsiae; Agapanthus gall midge: Enigmadiplosis agapanthi; Alder leaf beetle: Agelastica alni.

**Table 2**. Ranking of the most important diseases afflicting UK gardens. Score represents the mean importance score (maximum 5) given by survey respondents. Also tabulated is the ranked order of pests from RHS enquiry data and web hits.

|  |  |  |  |
| --- | --- | --- | --- |
| Order by survey | Score | Order by enquiries | Order by web hits |
| Late blight | 3.955 | Honey fungus | Rose black spot |
| Rose black spot | 3.331 | Phytophthora root rot | Powdery mildews |
| Powdery mildews | 3.259 | Box blight | Honey fungus |
| Rust diseases | 3.055 | Rust diseases | Late blight |
| Rots (Roots/stem/bulb) | 3.036 | Powdery mildews | Box blight |
| Rots (Fruits/flowers) | 2.913 | Leaf spots | Rots (Roots/stem/bulb) |
| Grey mould | 2.896 | Rots (Fruits/flowers) | Rots (Fruits/flowers) |
| Damping off | 2.851 | Cankers | Scab diseases |
| Downy mildews | 2.820 | Rots (Roots/stem/bulb) | Phytophthora root rot |
| Leaf spots | 2.765 | Grey mould | Club root |
| Wilts | 2.741 | Damping off | Rust diseases |
| Honey fungus | 2.735 | Snow mould | Wilts |
| Scab diseases | 2.698 | Plant viruses | Grey mould |
| Box blight | 2.651 | Fireblight | Fireblight |
| Plant viruses | 2.625 | Wilts | Red thread |
| Dutch elm disease | 2.579 | Downy mildews | Cankers |
| Club root | 2.572 | Scab diseases | Peach leaf curl |
| Ash dieback | 2.567 | Galls | Damping off |
| Cankers | 2.508 | Late blight | Silver leaf |
| Peach leaf curl | 2.326 | Silver leaf | Bleeding cankers |
| Silver leaf | 2.232 | Bracket fungi | Plant viruses |
| Bleeding cankers | 2.212 | Rose black spot | Coral spot |
| Phytophthora root rot | 2.171 | Dutch elm disease | Bracket fungi |
| Fireblight | 2.107 | Peach leaf curl | Leaf spots |
| Snow mould | 1.988 | Bleeding cankers |  |
| Coral spot | 1.918 | Coral spot |  |
| Bracket fungi | 1.861 | Club root |  |
| Red thread | 1.840 | Ash dieback |  |
| Galls | 1.711 | Red thread |  |

Species identities:

Late blight: *Phytophthora infestans*; Rose black spot: *Diplocarpon rosae*; Powdery mildews: species of fungi in the order Erisyphales; Rust diseases: mostly *Puccinia* spp. and *Uromyces* spp.; Rots of roots, stems and bulbs: variety of species, including *Phytophthora* spp., *Fusarium* spp and *Rhizoctonia* spp.; Rots of fruits and flowers: variety of species, including *Fusarium* spp. and *Monolinia* spp.; Grey mould: mostly *Botrytis cinerea*; Damping off: variety of species, including *Fusarium* spp., *Phytophthora* spp. and *Pythium* spp.; Downy mildews: variety of species in the Peronosporaceae; Leaf spots: wide variety of species, but excluding those specifically referred to here, such as rose black spot; Wilts: variety of species, including *Fusarium* spp. and *Verticillium* spp.; Honey fungus: genus *Armillaria*, mostly *A. mellea*; scab diseases: variety of species, including *Fusicladium* spp., *Spongispora* spp. and *Venturia* spp.; Box blight: *Calonectria pseudonaviculata* and *C. henricotiae*; Plant viruses: variety of species, including cucumber mosaic, Narcissus yellow stripe, raspberry yellows, tomato mosaic and tulip; Dutch elm disease: *Ophiostoma novo-ulmi*; Club root: *Plasmodiophora brassicae*; Ash dieback: *Hymenoscyphus fraxineus*; cankers: variety of species, including *Glomerella* spp., some bacteria (e.g. *Pseudomonas*) and *Neonectria* spp. ; Peach leaf curl: Taphrina deformans; Silver leaf: Chondrostereum purpureum; Bleeding cankers: various Phytophthora spp.; Phytophthora root rot: various Phytophthora spp. including P. *cinnamomi* and *P. cryptogea*; Fireblight: Erwinia amylovora; Snow mould: Microdochium nivale; Coral spot: Nectria cinnabarina; Bracket fungi: variety of species, mostly Fistulina hepatica, Ganoderma spp., Inonotus spp. and Piptoporus betulinus; Red thread: Laetisaria fuciformis; Galls: variety of species, including Exobasidium spp. and Taphrina spp.

**Table 3**

Results of Kruskal Wallis Analysis of Variance, testing for differences in importance value of insect pests across the 12 geographical regions of the UK. ‘Figure’ corresponds to that depicting the data, in Fig. 3 or Supplementary information. Degrees of freedom = 11 in all cases.

|  |  |  |  |
| --- | --- | --- | --- |
| pest | χ2 value | P | Figure |
| Slugs & snails | 16.57 | 0.121 | 3A |
| Aphids | 13.17 | 0.282 | S1A |
| Blackfly | 42.95 | <0.001 | S1B |
| Cabbage caterpillars | 25.99 | <0.01 | S1C |
| Vine weevil | 12.97 | 0.295 | S1D |
| Carrot fly | 33.74 | <0.001 | S1E |
| Lily beetle | 31.19 | <0.001 | 3B |
| Glasshouse whitefly | 18.81 | 0.065 | S1F |
| Codling moth | 17.51 | 0.0937 | S1G |
| Cabbage root fly | 23.9 | <0.05 | S1H |
| Horse chestnut leaf miner | 29.02 | <0.01 | S1I |
| Glasshouse red spider mite | 9.16 | 0.606 | S1J |
| Mealybug | 20.79 | <0.05 | S1K |
| Allium leaf miner | 34.37 | <0.001 | S1L |
| Woolly aphid | 9.22 | 0.601 | S1M |
| Chafer grubs | 7.61 | 0.749 | S1N |
| Leatherjackets | 9.79 | 0.549 | S1O |
| Soft scale | 8.17 | 0.697 | S1P |
| Cherry blackfly | 13.21 | 0.28 | S1Q |
| Mice & voles | 16.37 | 0.128 | S1R |
| Rosy apple aphid | 14.14 | 0.225 | S1S |
| Viburnum beetle | 11.41 | 0.409 | S1T |
| Rosemary beetle | 29.38 | <0.01 | SU |
| Glasshouse thrips | 9.82 | 0.546 | S1V |
| Rose leaf rolling sawfly | 7.47 | 0.76 | S1W |
| Rabbits | 20.09 | <0.05 | S1X |
| Tortrix moth caterpillar | 14.64 | 0.199 | S1Y |
| Berberis sawfly | 17.51 | 0.0936 | S1Z |
| Box tree moth | 12.59 | 0.32 | 3C |
| Moles | 15.56 | 0.153 | S1AA |
| Cushion scale | 20.57 | <0.05 | S1AB |
| Cypress aphid | 18.17 | 0.077 | S1AC |
| Chrysanthemum leaf miner | 11.56 | 0.397 | S1AD |
| Fuchsia gall mite | 16.83 | 0.112 | S1AE |
| Agapanthus gall midge | 14.58 | 0.202 | S1AF |
| Alder leaf beetle | 7.51 | 0.757 | S1AG |

Table 4

Results of Kruskal Wallis Analysis of Variance, testing for differences in importance value of diseases across the 12 geographical regions of the UK. ‘Figure’ corresponds to that depicting the data, in Fig. 4 or Supplementary information. Degrees of freedom = 11 in all cases.

|  |  |  |  |
| --- | --- | --- | --- |
| disease | χ2 value | P | Figure |
| Late blight | 12.66 | 0.316 | 4A |
| Rose black spot | 23.01 | < 0.05 | 4B |
| Powdery mildews | 7.63 | 0.746 | S2A |
| Rust diseases | 18.08 | 0.079 | S2B |
| Rots (Roots/stem/bulb) | 15.52 | 0.159 | S2C |
| Rots (Fruits/flowers) | 15.27 | 0.17 | S2D |
| Grey mould | 16.17 | 0.135 | S2E |
| Damping off | 14.74 | 0.195 | S2F |
| Downy mildews | 8.33 | 0.683 | S2G |
| Leaf spots | 6.92 | 0.806 | S2H |
| Wilts | 12.58 | 0.322 | S2I |
| Honey fungus | 16.15 | 0.136 | S2J |
| Scab diseases | 10.65 | 0.473 | S2K |
| Box blight | 10.55 | 0.482 | S2L |
| Plant viruses | 16.21 | 0.134 | S2M |
| Dutch elm disease | 8.33 | 0.684 | S2N |
| Club root | 27.76 | < 0.01 | 4C |
| Ash dieback | 9.33 | 0.591 | S2O |
| Cankers | 12.42 | 0.333 | S2P |
| Peach leaf curl | 5.87 | 0.881 | S2Q |
| Silver leaf | 19.48 | 0.053 | S2R |
| Bleeding cankers | 15.16 | 0.175 | S2S |
| Phytophthora root rot | 27.14 | < 0.01 | S2T |
| Fireblight | 14.15 | 0.225 | S2U |
| Snow mould | 21.45 | < 0.05 | S2V |
| Coral spot | 0.87 | 0.634 | S2W |
| Bracket fungi | 7.99 | 0.714 | S2X |
| Red thread | 10.06 | 0.525 | S2Y |
| Galls | 8.95 | 0.626 | S2Z |

**Figure S1**

What are the predominant pests and diseases afflicting gardens in the UK?

Mean (± one standard error) importance value for various pests across geographic regions of the UK. Key to x axis: GL: Greater London, SE: south east England; SW: south west England, WM: west Midlands; EM: east Midlands; EE: eastern England, NW: north west England; NE: north east England; YH: Yorkshire and Humberside; NI: Northern Ireland; SC: Scotland and W: Wales.























**Figure S2**

What are the predominant pests and diseases afflicting gardens in the UK?

Mean (± one standard error) importance value for various diseases across geographic regions of the UK. Key to x axis: GL: Greater London, SE: south east England; SW: south west England, WM: west Midlands; EM: east Midlands; EE: eastern England, NW: north west England; NE: north east England; YH: Yorkshire and Humberside; NI: Northern Ireland; SC: Scotland and W: Wales.

















