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Grape Expectations: A Survey of British Vineyard Land Management Practices From an Environmental Perspective

Janine Griffiths-Lee*, Dave Goulson and Elizabeth Nicholls

School of Life Sciences, University of Sussex, Brighton, UK

*Corresponding author: J.Griffiths-Lee@sussex.ac.uk

ORC-ID:

Griffiths-Lee: 0000-0003-4179-2633

Nicholls: 0000-0002-3697-0223

Goulson: 0000-0003-4421-2876

Abstract

Traditional vineyard landscapes are generally intensively managed with heavy reliance on synthetic pesticides. Viticulture is one of the fastest-growing sectors of English agriculture and information on land management is essential to secure a sustainable future. We surveyed viticulturists to ascertain vineyard pest presence, pest control, inter-row ground cover and wildflower use. The majority of viticulturists reported the presence of vineyard pests and relied heavily on pesticides, with 74% using synthetic pest control, 40% using herbicides, 40% using fungicides. Inter-row, 66% of vineyards have grass-only cover and frequent summer mowing, with only 6% sowing wildflowers. However, 60% use natural pest control, 80% reported existence of wildflowers in headlands, and 29% mentioned reduced mowing. We discuss spontaneous and sown wildflowers and benefits for biodiversity, integrated pest management and the commonly perceived barriers to adaptation. We conclude there is huge variation in management styles and more evidence-based environmental advice for viticulturists is needed.

Keywords: pest control; habitat management; viticulture; wildflowers; IPM.

Introduction

Globally, around 7.4 million hectares of land is currently cultivated by wine or table grapes (*Vitis* spp.) (OIV 2019). Ongoing conversion of natural habitats to viticulture is to the detriment of biodiversity in many of the world's top wine-producing regions (Armesto et al 2010; Fairbanks et al 2004; Merenlender 2000), particularly since traditional vineyard landscapes are generally intensively managed with heavy reliance on synthetic chemical pesticides (Urruty et al 2016). Synthetic pesticides are of great concern to human health and the wider environment, and more sustainable and ecological methods in agricultural food production are urgently needed (Nicolopoulou-Stamati et al 2016).

Grapevines cannot benefit from crop rotation or changes to cropping systems practised in traditional agriculture, and this can increase pressure from pests. *Erysiphe necator* (powdery mildew), *Plasmopara viticola* (downy mildew) and *Botrytis cinerea* (botrytis, or grey mould) are among the most important pests, and the fungicides used to treat these diseases account for the majority of pesticide treatments in European vineyards (Pertot et al 2017). Insecticide use against arthropod grape pests is currently low in European vineyards (Pertot et al 2017), although the emergence of new vineyard pests due to shifts in distributions under a changing climate is of concern (Reineke and Thiery 2016).

There are common approaches to integrated pest management (IPM) practised in European viticulture. These include the use of resistant varieties, semiochemicals, biopesticides, biological pest control, and pest monitoring combined with the use of epidemiological mathematical models to schedule and limit pesticide use (Pertot et al 2017). Biopesticides are not as widely used as synthetic pesticides due to cost, shelf-life and lower effectiveness, but potassium bicarbonate and seaweed extracts, for example, are common alternatives to chemical fungicides to treat downy mildew (Pertot et al 2017).

The planting scheme commonly practised in viticulture leaves a large portion of uncultivated and untilled soil between the vine rows. Diversity of soil-dwelling organisms and surface organic matter generally decrease with increasing tillage intensity in agriculture (Roger-Estrade et al 2010). Minimising tillage is also beneficial for bee diversity because of the encouragement of perennial flowers (McHugh et al 2022), and therefore vineyards have great potential to support biodiversity because of they are not regularly tilled.

In agricultural environments, sown wildflower strips are often implemented to provide resources for pollinators (Blaauw and Isaacs 2014) and although grapevines do not have an obligate relationship with pollinators, the establishment of wildflowers in these typically monocultured landscapes is beneficial for biodiversity. For example, studies on inter-row plantings of wildflowers in wine-growing regions conclude that they increase the richness and abundance of wild bees (Kehinde and Samways 2014; Kratschmer et al 2019; Kratschmer et al 2021; Wilson et al 2018).

Wildflower strips also provide essential resources for natural enemies of pests (Landis et al 2000). In vineyards, inter-row wildflowers are beneficial for insect parasitoids (Judt et al 2019) and other natural enemies (Abad et al 2021a). By reducing vine vegetative growth, cover crops in inter-row alleys also reduce the incidence of fungal diseases such as mildew (Abad et al 2021b) and are a traditional alternative to using herbicides to control inter-row vegetation in vineyards (Pertot et al 2017). In addition to supporting biodiversity and pest control services, wildflowers in a vineyard enhance numerous other ecosystem services with positive effects on soil organic carbon, water infiltration, and soil erosion reduction (Abad et al 2021a).

There are also benefits to reducing mowing, thereby encouraging the spontaneous flowering plant species that grow in vineyard inter-rows. Low-intensity meadows with less frequent mowing have a higher diversity of plants, bees and butterflies (Weiner et al 2011). Reducing mowing frequency enhances insect diversity (Del Toro and Ribbons 2020; Wastian et al 2016) and in a vineyard setting has been found to benefit parasitic wasps (Zanettin et al 2021).

In Great Britain, vineyard coverage has quadrupled since 2000, with around 800 vineyards and approximately 3,300 ha of land under vine (WineGB 2021a). Ninety-eight per cent of these vineyards are based in England (WineGB 2021a). UK agri-environmental schemes have yet to make specific recommendations to support biodiversity in viticulture, despite it being one of the fastest-growing sectors of English agriculture (South Downs National Park Authority (SDNPA) 2021). Considering this growth, there is huge potential to establish sustainable, environmentally friendly land management practices while this production system is still in its relative infancy. We conducted a survey on vineyard owners and managers in Great Britain, to ascertain land management and pest-control preferences, and to establish research priorities to support a sustainable future for this sector. We wanted to understand: 1) most frequent pests present 2) synthetic and natural pest control methods employed 3) use of inter-row ground cover 4) use of wildflowers in the vineyard and 5) information resources used to support decisions.

Method

A survey was created to evaluate the land management practices of vineyard owners or managers (viticulturists). The main themes of the survey were pest abundance, pest-control methods, synthetic chemical use, mowing regime, utilisation of wildflowers and information sources used to make management decisions. The survey consisted of 15 questions and was a combination of multiple choice and free text (Supplementary information S1 lists the survey questions). The survey was circulated to British vineyards via 'WineGB' members and by direct contact. Available online (hosted on 'Qualtrics') and as a word document, the survey was open for four weeks during June-July 2021. Vineyards could choose to remain anonymous.

Thematic analysis was conducted on the free text options across all responses (Braun and Clarke 2006), identifying key themes and the frequency these were mentioned. If a vineyard mentioned the same theme across multiple answers, this was still classed as a single count. Due to the range of responses, only themes with a count of two or more are presented in this study. Graphs were produced in R (R core team 2020) using *ggplot2*.

Results

Viticulturists from 35 British vineyards responded to the survey with full responses that could be used in the analysis. The majority of vineyards were based in the South of England: 43% in the South West and 37% in the South East (Fig.1). The remaining vineyards were evenly distributed in the East Midlands, East of England, Wales, and the West Midlands. The size of the vineyards ranged from 0.1 ha to 94 ha, with a mean of 8.9 ha (median of 2.75 ha) and more recently established vineyards were generally smaller (Fig.2). The majority of vineyards had vines that had been established for 10-15 years (Fig.2), the oldest vines were planted 42 years ago.

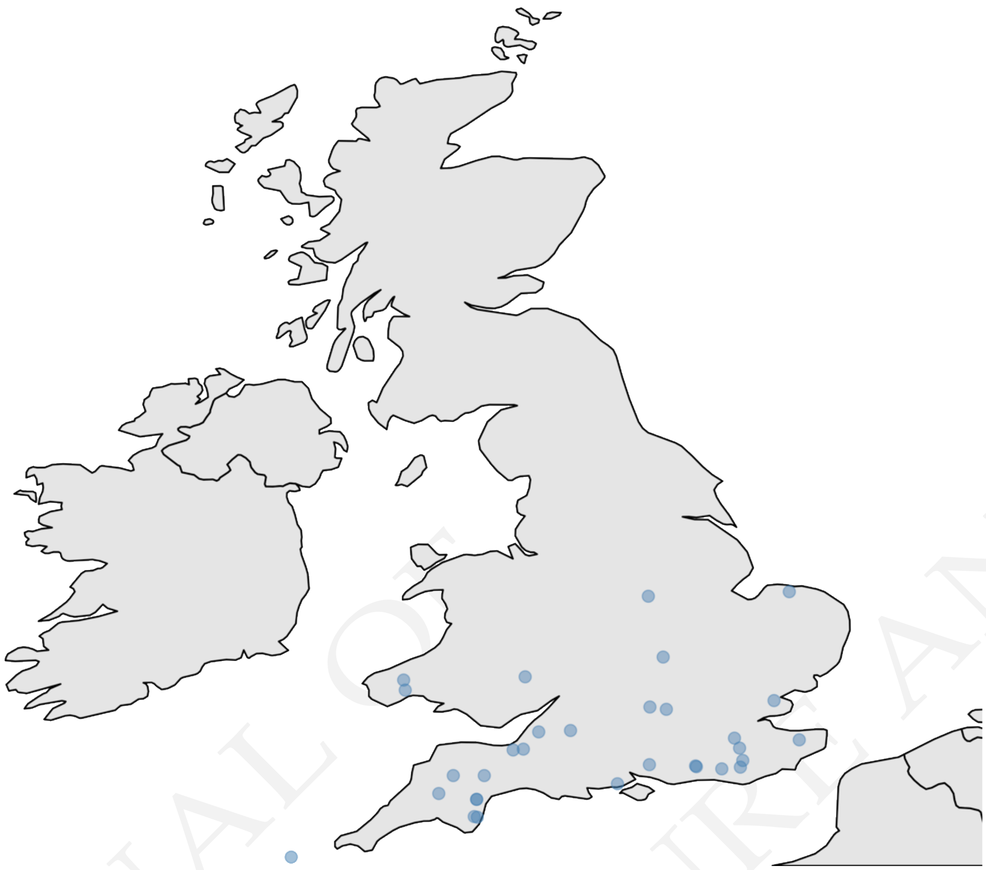

Figure 1. Map of Great Britain showing the approximate locations (lat/long) of non-anonymised vineyards participating in the survey.

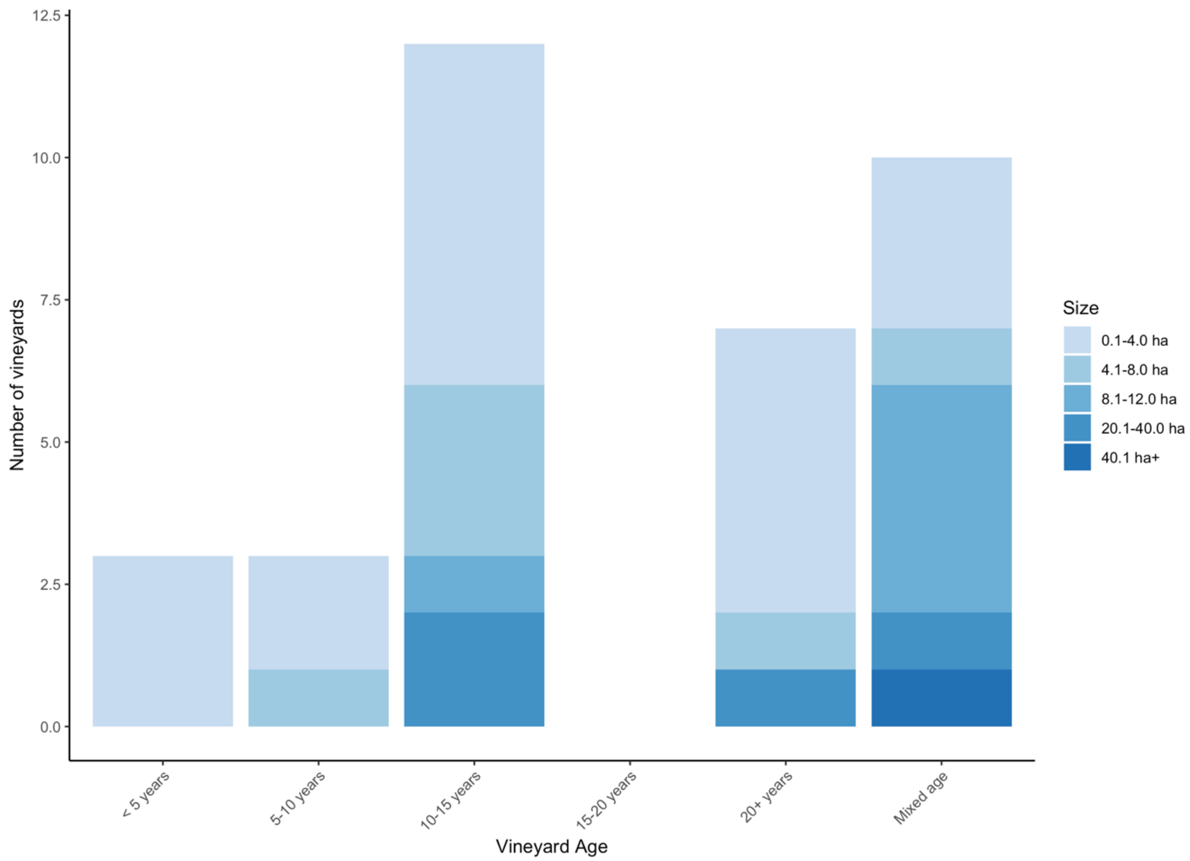

Figure 2. Size in hectare (ha) of 35 participating vineyards, grouped by size (0.1-4.0 ha, 4.1-8.0 ha, 8.1-12.0 ha, 12.1-20.0 ha, 20.1-40.0 ha, 40.1 ha +) and time since establishment (<5 years, 5-10 years, 10-15 years, 20+ years, mixed age. No data for 15-20 years).

Vineyard pests

In response to the question *'Could you please tell us about the pests that are a problem at your vineyard, including any you have eradicated, or are an ongoing problem?'*, pests were grouped into vertebrate pest, insect pest, and fungal pest (which also included oomycetes). 74% reported the presence of pests in their vineyard (Fig.3) detailing current, seasonal or historic pests. The majority of viticulturists reported the presence of one distinct vineyard pest of any type, although the presence of up to seven distinct pests was reported (Fig.4). Over half of viticulturists reported the presence of at least one insect pest species (Fig.3) with the majority of those reporting just one insect pest species (Fig.5). Wasps were the most commonly reported pest, mentioned by 31% of viticulturists (Table 1). Although not explicitly stated, we assume these to be common social wasps, as they were described to feed on grapes. Birds were mentioned by 20% of viticulturists, mildew (both downy and powdery) by 17%, and botrytis by 11% of viticulturists (Table 1). Deer were mentioned by 11% of viticulturists and were perceived to cause damage by eating the younger vines.

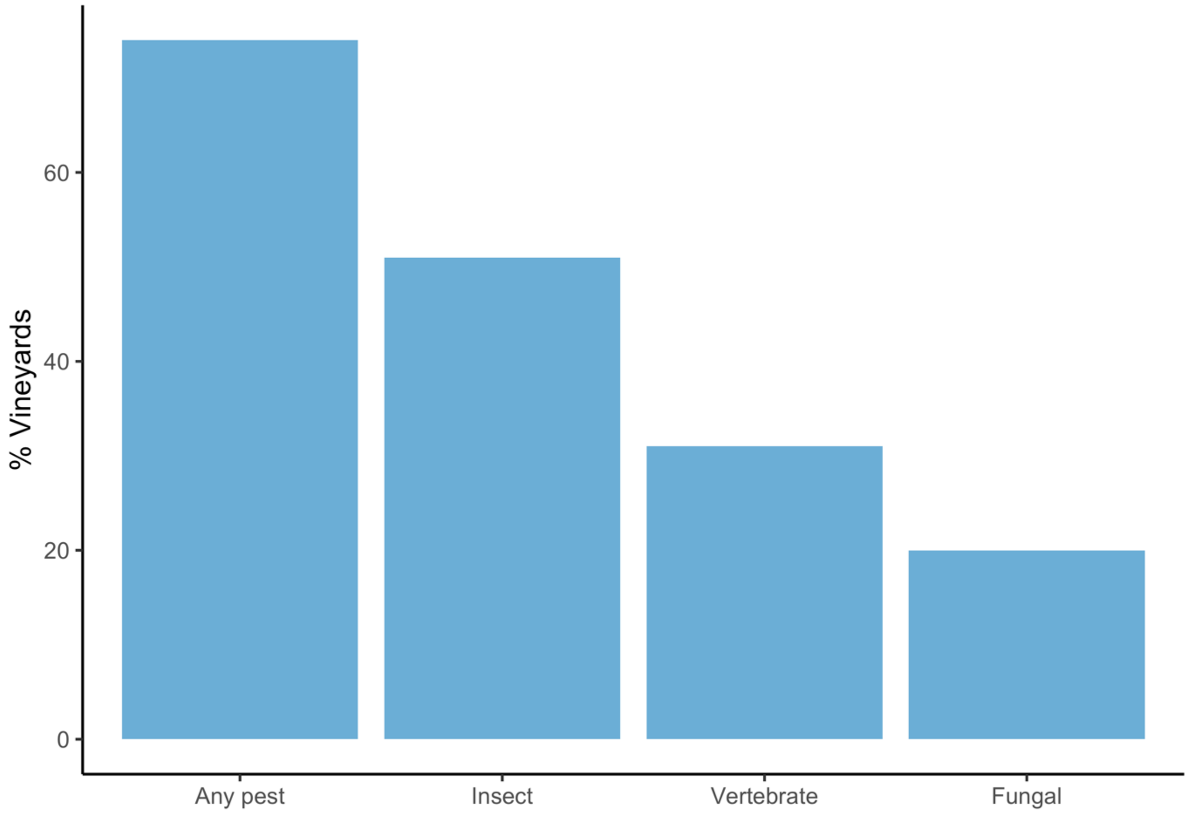

Figure 3. Percentage presence/absence of pests in vineyard responding to the survey. Presented as any pest, insect pest, vertebrate pest, and fungal pest. Sample size n=35 vineyards.

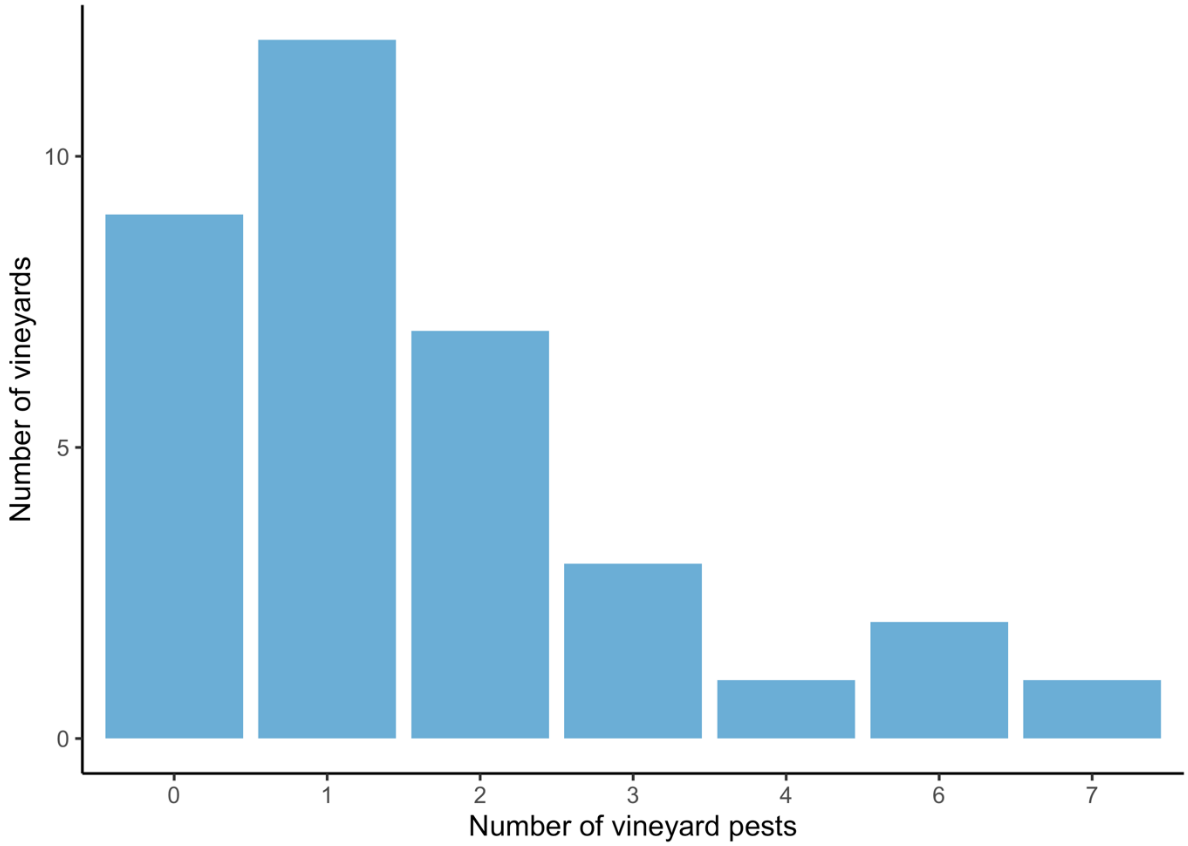

Figure 4. Count of all distinct pests (combining insect, vertebrate, or fungal) recorded in vineyards. Response to question – 'Could you please tell us about the pests that are a problem at your vineyard, including any you have eradicated, or are an ongoing problem?' Sample size n=35 vineyards.

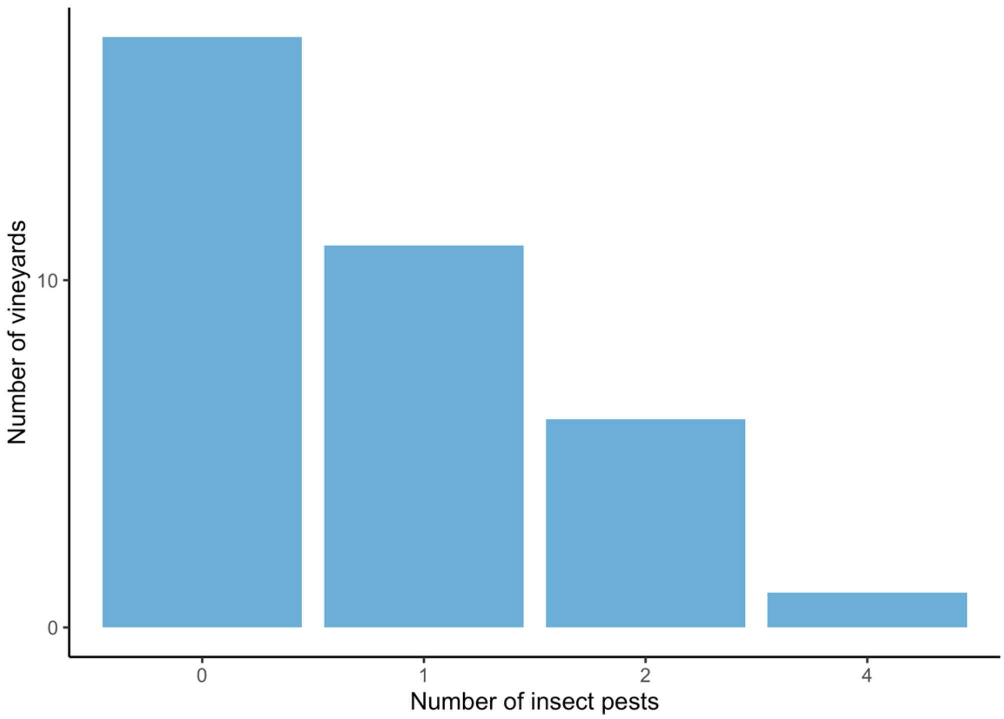

Figure 5. Counts of distinct insect pests recorded in vineyards. Sample size n=35 vineyards.

Theme	Vineyard	Theme	Vineyard
Pest		**Flowers in headlands**	
Spotted wing drosophila	11%	Bird's foot trefoil	17%
Wasps	31%	Chicory	6%
Badgers	11%	Vetch	11%
Botrytis	11%	Clover	20%
Mildew (powdery and downy)	17%	Wild marjoram	6%
Birds	20%	Teasel	6%
Little brown apple moths	6%	Scarlet pimpernel	6%
Thrips	11%	Cowslip	6%
Deer	11%	Dandelion	6%
Mites	6%	**Barriers to using sown wildflowers**	
Natural pest control		Natural regeneration sufficient	20%
Seaweed extract	11%	Under consideration	11%
Exclusion netting / fencing	6%	Cost and/or logistics	17%
Potassium bicarbonate	11%	**Other**	
Nettle extract	6%	Hedgerows	9%
Wasp and *Drosophila* traps	20%	Reduced mowing	29%
Wildflowers	9%	Natural regeneration establishment	11%
Pest and land management advice			
Online, book, published research	43%		
Other vineyards	11%		
Agronomist/ecologist	26%		
Consultants	14%		
No advice needed	9%		
WineGB	14%		

Table 1. Thematic analysis and % of viticulturists that mention themes, across all survey free-text responses.

Synthetic chemical pest control

In response to the question *'Are you an organic vineyard?'*, 14% were certified organic (Fig.6) and a further 11% of vineyards reported practising organic methods but were not officially certified.

In response to the question *'Do you use any chemical treatments to eradicate insect pests or vine diseases at your vineyard?'* and if the answer was 'yes': *'If you are happy to tell us more about the chemical treatments used for insect pests or vine diseases, please do so here. Such as: Chemical treatment name, Applications per year, Target pest, % Effectiveness'*, we found synthetic chemical pest control to be widespread in those British vineyards responding to our survey (74%) (Fig.6). The majority of synthetic treatments reported were fungicides with 40% of viticulturists listing these treatments. Spraying regime varied greatly, with comments stating 'early in the season only', 'throughout the season', and 'every 10-14 days'. The number of products used also varied greatly from vineyard to vineyard, ranging from one to 13 fungicide products. Although not strictly classified as synthetic, we have included copper oxychloride fungicide here because of its effects on edaphic biodiversity and persistence in soils, which was mentioned by 6% of viticulturists. Only 9% of viticulturists listed the use of chemical insecticides. Thematic analysis specifically on synthetic chemical use for pest control was not possible, due to the range of products, ingredients, and spraying regimes followed.

In response to the question '*Do you use weed killer or herbicide between vine rows?*' and if the answer was 'yes': *'If you are happy to do so, please tell us what weed killer or herbicide you use'*, 40% of viticulturists reported using herbicide (Fig.6). Of those responding positively to this question, glyphosate was used by 85% with the remaining viticulturists failing to disclose which herbicide they used.

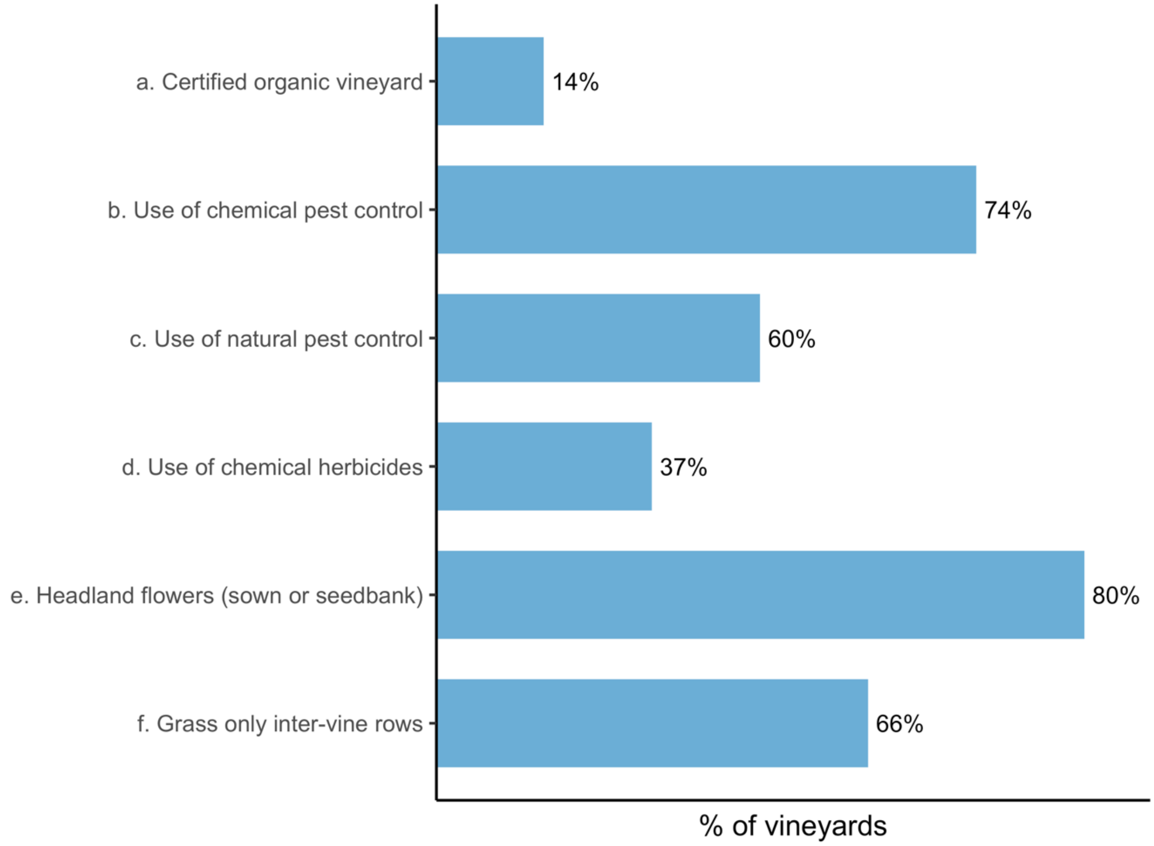

Figure 6. Land management and pest-control preferences, percentage responding 'Yes' to a) 'Are you an organic vineyard? b) 'Do you use any chemical treatments to eradicate insect pests or vine diseases at your vineyard?' c) 'Do you use any natural methods to eradicate insect pests or vine diseases at your vineyard?' d) 'Do you use weed killer or herbicide between vine rows?' e) 'Do you have any sown wildflower margins, or areas of natural flower regeneration in the land surrounding the vines?' and responding 'grass only' to question f) 'What type of ground cover do you have in-between your vines?'. Sample size n=35 vineyards.

Natural pest control

In response to the question '*Do you use any natural methods to eradicate insect pests or vine diseases at your vineyard?*' and if 'yes': '*If you are happy to tell us more about the natural methods used for insect pest eradication or vine disease, please do so here. Such as: Natural method name, Applications per year, Target pest, % Effectiveness*', 66% of viticulturists use natural (ie. non-synthetic chemical) methods of pest control (Fig.6), while 54% use both natural and synthetic pest-control methods. The most commonly used natural pest control methods were traps (mostly for wasps, but also *Drosophila*), mentioned by 20% of viticulturists. Wildflowers in the context of pest control were mentioned by 9% of viticulturists. Seaweed extract and potassium bicarbonate were both reported to be sprayed on vines for natural pest control in 11% of vineyards (Table 1).

Inter-row ground cover and headlands

In response to the question '*What type of ground cover do you have in-between your vines*?' 66% of viticulturists reported the growth of grass inter-row (Fig.6). This space was reported to be mowed often during the spring and summer months, with frequency of mowing ranging from every 10 days to once a month. Twenty-eight per cent reported or identified spontaneously-occurring wildflower species in the inter-row alleys. Six per cent of viticulturists sow wildflower seeds in inter-row alleys to supplement the naturally occurring flowering species (Fig.6).

In response to the question '*Do you have any sown wildflower margins, or areas of natural flower regeneration in the land surrounding the vines?*' and if the answer was 'yes', '*Please tell us more, such as which wildflowers you sow*', 80% reported flower margins or headlands around the vines (Fig.6). Forty per cent of viticulturists relied on natural regeneration of spontaneously occurring flowering species, while 20% mentioned wildflowers being supplemented with wildflower seeds in the margins and headlands. The most frequently mentioned flowering species were *Lotus corniculatus* (bird's foot trefoil) and *Trifolium* species (clovers), although we could not ascertain if these were sown or spontaneous (Table 1). The majority of wildflowers reported were native species.

Responding to the free text question *'If you don't use flowers in-between vine rows or in the margins around your vines, is this something you are thinking about doing? If not, could you tell us why?'*, 20% of the viticulturists felt the natural regeneration of wildflowers was sufficient, although 11% said they would consider sowing wildflowers in the future (Table 1). Seventeen per cent of the viticulturists mentioned cost and/or logistics as a factor in sowing wildflowers at the vineyard. One viticulturist elaborated and told us that mown grass is easier to walk on for long hours compared to taller vegetation. Another perceived barrier was the potential for mildew resulting from the sowing of wildflowers inter-row, while another viticulturist stated it was a 'silly idea'.

The benefits of reduced or delayed mowing for pest control/wildlife was mentioned by 29% of viticulturists, and the benefits of hedgerows by 9% (Table 1). The time taken for natural regeneration to establish a diverse floral community was mentioned by 11%, with viticulturists stating it took at least 10 years.

Land management and pest control information sources

In response to the free text question *'Where do you get advice on pest treatments and land management?'*, many of the viticulturists reported using multiple sources of information for decisions on pest treatment and land management. Forty-three per cent of viticulturists mentioned books or online resources for research, and 26% mentioned agronomists or ecologists (Table 1). Other sources of advice included consulting other vineyards (11%), the use of consultants (14%) and contacting WineGB (14%). Nine per cent of viticulturists reported not needing advice on pests and land management.

Discussion

We surveyed 35 vineyard owners or managers to understand current land management practices in British viticulture, gathering key information on vineyard pest abundance, pest-control methods, synthetic chemical use, mowing regimes and the utilisation of wildflowers in vineyard landscapes. We conclude there is considerable variation in management styles and the resources used to inform practices in British viticulture.

Nearly three quarters of vineyards responding to our survey used some form of synthetic chemical pest control (excluding herbicides) and just 14% of the vineyards were certified organic. Just 9% of vineyards reported using insecticides, which accords with their reported low use in European vineyards (Pertot et al 2017). Synthetic herbicide use was reported by 40% of viticulturists, with the majority of those (85%) using glyphosate. The most widely used herbicide across the agricultural sector (Baylis 2000), the safety of glyphosate is subject to ongoing debate, with numerous studies investigating its impacts on human health (see Nicolopoulou-Stamati et al 2016 and references therein) and negative impacts on bees (Motta et al 2018; Straw et al 2021).

Pests were present in the majority of British vineyards (including vertebrate, insect and fungal pests) and over half of vineyards had at least one insect pest. Wasps were the most common pest in the vineyards and were typically controlled using natural methods such as wasp traps. Downy and powdery mildew, and botrytis were mentioned by a smaller percentage of viticulturists (17% and 11% respectively) although fungicides used for controlling these diseases were the most reported synthetic chemical treatments used. There was also a large variation in spraying regimes reported between vineyards. Similarly, in European vineyards, fungicides to treat botrytis and mildew account for the majority of pesticide use (Pertot et al 2017). Given that fungicides have negative effects on non-target species, including sub-lethal and lethal effects on bees (Cullen et al 2019) there is potential to improve sustainability by the recommendation and further research of alternative methods to control fungal pests.

Wildflowers can provide a natural alternative to herbicides, fungicides and insecticides for certain pests. A systematic review on the effects of inter-row crop cover found a reduction in vine vegetative growth, and an associated reduction in the incidence of fungal disease in 67% of studies (Abad et al 2021b). These studies recorded reductions in the incidence of powdery mildew and botrytis, both frequently listed as pests by vineyards in our study. Additionally, a traditional and natural alternative to herbicide-use in viticulture is cover cropping or shallow tillage (Pertot et al 2017). Furthermore, studies on inter-row plantings in traditional wine-growing regions to benefit biodiversity and natural pest control of insect pests are numerous (Abad et al 2021b and references therein; Judt et al 2019; Kehinde and Samways 2014; Kratschmer et al 2019; Kratschmer et al 2021; Wilson et al 2018).

Two thirds of viticulturists reported the growth of grass only in inter-row alleys. We presume at least some of these vineyards had smaller flowering plant species spontaneously appear through natural regeneration in between the mowing regime, although these vineyards reported to frequently mow the grass in the spring and summer months. Encouragingly, the benefits of reduced or delayed mowing for pest control/wildlife was recognised by nearly one-third of vineyards. Only 6% of vineyards reported supplementing naturally-occurring flowering species with wildflower seeds inter-row, and only 9% of vineyards acknowledged wildflowers in the context of pest control. There is therefore considerable potential to raise awareness on the benefits of sown wildflowers for biodiversity, natural pest control and reducing reliance on synthetic chemicals.

We identified commonly perceived barriers to sowing wildflowers inter-row through our thematic analysis, such as flowers growing too tall, and this causing potential problems accessing the vines and potentially increasing humidity; an issue also reported in Californian viticulture (Wilson and Danne 2017). However, actively managing floral cover at a maximum height of 20 cm in cherry orchards was found to provide favourable pest control services, limit humidity impacts on the crop and to facilitate access (Mateos-Fierro et al 2021). It would be valuable to research the impact of similar management in a vineyard landscape.

The majority of viticulturists reported the presence of flower margins in the vineyard headlands, and twice as many vineyards rely on natural regeneration rather than sowing wildflower seeds. However, headlands may not have as many benefits for providing natural pest control services when compared to allowing the natural regeneration or sowing of wildflowers in inter-row alleys. Inter-row plantings would act as corridors, encouraging natural enemies of pests to spill over into vines by increasing movement (Woodcock et al 2016). Some vineyards considered the spontaneous natural regeneration of headland wildflowers to be sufficient, with no need to supplement this with seeds. Indeed, seedbank in agricultural landscapes has been shown to have high floral diversity of flowers favourable to pollinators (Warzecha et al 2018). Bird's foot trefoil and clovers received frequent mention by viticulturists and are well known to support pollinators (Cole et al 2022; Wood et al. 2015), which is encouraging for the provision of food resources for pollinating insects in a vineyard landscape. Previous research has shown that targeted sowing of particular plant species rather than simply increasing overall plant richness is often more beneficial for pollinators (Warzecha et al 2018). Supplementing existing flowers with low-lying species such as dandelions (*Taraxacum* agg.) which are high in pollen and nectar (Hicks et al 2016) would provide valuable resources to support biodiversity.

A potential caveat of our study is that the use of pest control methods, and the presence of pests are self-reported. More experienced viticulturists or those with an ecological background may be able to conduct a more systematic survey of pests or damage from pests, so there could potentially be biases in reporting. Further research into land management and pest control methods could incorporate vineyard surveys by trained experts, or more detailed interviews with viticulturists and consultants.

Overall, the use of synthetic pest control products and the spraying regimes varied greatly. The resources and information sources used by vineyards on land management and pest control were also highly variable, and from the current survey we could not ascertain if these sources practised sustainable, organic or more traditional techniques. Established in 2019, the Sustainable Wines of Great Britain had 61 members as of 2021, accounting for 33% of the area of Great Britain under vine (WineGB 2021b), and has great potential to inform Great British vineyards of sustainable evidence-based practices as it grows in membership. Additionally, decision-support systems in IPM methods could reduce reliance on chemical pesticides (Pertot et al 2017).

The majority of vineyards responding to our survey were based in the South East and South West of England. These regions are experiencing rapid growth in the viticulture industry; In the South Downs National park, for example, there has been a 90% increase in the coverage of vines since 2016 (SDNPA 2021). We suggest that further research on natural pest-control methods, evidence-based IPM and enhancing biodiversity in English vineyards is needed to improve the sustainability of this sector. The use of sown and spontaneous wildflowers in inter-row alleys as part of a suite of IPM methods may limit the reliance on synthetic chemicals, which are routinely used by Great British vineyards and beyond. As we have discussed, wildflowers can reduce incidence of mildew and botrytis, are traditional alternatives to herbicide use, provide essential resources for the natural enemies of insect pests, benefit wider biodiversity and support multiple ecosystem services.

Author contributions

All authors conceived the methodology and questions; JGL collected and analysed the data, and led the writing of the manuscript. All authors gave final approval for publication. The authors report no conflicts of interest.

Ethics approval

The University of Sussex Sciences & Technology Cross-Schools Research Ethics Committee (C-REC) granted Ethical approval to carry out this work (project reference number ER/JG411/1).

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