Perennial flower strips can be a cost-effective tool for pest suppression in orchards

Journal of Agricultural Economics

JAE Journal of Agricultural Economics

ORIGINAL ARTICLE OPEN ACCESS

Perennial Flower Strips Can Be a Cost-Effective Tool for Pest Suppression in Orchards

Charlotte Howard[1] | Paul J. Burgess[2] | Michelle T. Fountain[3] | Claire Brittain[4] | Michael P. D. Garratt[1]

[1]Centre for Agri-Environmental Research, School of Agriculture, Policy and Development, University of Reading, Earley Gate, Reading, UK | [2]Cranfield University, Cranfield, Bedfordshire, UK | [3]NIAB, Kent, UK | [4]Syngenta, Jealott's Hill International Research Centre, Warfield, Bracknell, UK

Correspondence: Charlotte Howard (c.howard@reading.ac.uk)

Received: 22 July 2024 | **Revised:** 11 February 2025 | **Accepted:** 18 March 2025

Funding: This work was financially supported by Syngenta and the Biotechnology and Biological Sciences Research Council (BBSRC), part of UK Research and Innovation (UKRI) with the FoodBioSystems Doctoral Training Partnership (FBSDTP) (BB/T008776/1).

Keywords: bio-economic model | cost–benefit | crop damage | financial analysis | flower margin | pest control | yield

ABSTRACT

Flower strips can provide many economic benefits in commercial orchards, including reducing crop damage by a problematic pest, rosy apple aphid (*Dysaphis plantaginea* [Passerini]). To explore the financial costs and benefits of this effect, we developed a bio-economic model to compare the establishment and opportunity costs of perennial wildflower strips with benefits derived from increased yields due to reduced *D. plantaginea* fruit damage under high and low pest pressure. This was calculated across three scenarios: (1) a flower strip on land that would otherwise be an extension of the standard grass headland, (2) a flower strip on land that could otherwise be used to produce apples and (3) a flower strip in the centre of an orchard. Through reduction of *D. plantaginea* fruit damage alone, our study shows that flower strips on the headland can be a positive financial investment. If non-crop land was not available, establishment of a flower strip in the centre of an orchard, instead of the edge, could recoup opportunity costs by providing benefits to crops on both sides of the flower strip. Our study can help guide the optimal placement of flower strips and inform subsidy value for these schemes.

1 | Introduction

It has been estimated that between 8% and 15% of the global yield of six major annual crops is lost due to pest damage (Oerke 2006). Pest populations can multiply rapidly without suppression from their natural predators and parasites (natural enemies) (Karp et al. 2013) and the loss of natural habitat and landscape features in agricultural landscapes can have negative impacts on organisms essential for pest-control services (Dainese et al. 2019; Emmerson et al. 2016). Habitat management on or around farms, for example, flower strips (Crowther et al. 2023), can mitigate these effects by providing resources for natural enemies, thereby reducing reliance on chemical pest-control (Cahenzli et al. 2017; Judt et al. 2023).

Flower strips can provide breeding and food resources for natural enemies year-round and from year-to-year. They can be sown or naturally generated and can border the crop, often on unproductive land, or as strips between the crop rows (Fountain 2022). The optimal size needed for biological control is uncertain, but larger areas are expected to increase biological control services (Blaauw and Isaacs 2012). Sown perennial flower borders can increase the abundance and diversity of natural enemies, both in the border and adjacent crop, and can reduce pest abundance in comparison to fields with only grass borders (Crowther et al. 2023). Spill-over of biocontrol benefits from a flower strip into an orchard is uncertain and likely context specific, but effects up to 50 m into the crop area have been recorded (Howard et al. 2024; Wyss 1995; Woodcock et al. 2016) with evidence of reduced crop pest damage (Crowther et al. 2023; Howard et al. 2024). Importantly, flower strips have a host of additional benefits; for example: improving pollination (Ortega-Marcos et al. 2022), soil protection and increasing biodiversity (Haddaway et al. 2018).

Although sown flower strips provide benefits, they also incur costs. These include the capital costs of establishment, such as the seed mix and ground preparation. There are also ongoing maintenance costs, although less than establishment costs, which can comprise one to two cuts per year, preferably with the cuttings removed (Carvell et al. 2022). A second potential cost is the opportunity cost of the land used for the flower strips, which in some instances could be used for additional crop (Kleijn et al. 2019). As such, the creation of flower-rich plots on farmland has been subsidised in the UK, EU and USA. Governmental agri-environmental schemes can offer financial incentives for flower-rich plots as part of Integrated Pest Management (IPM) strategies to support biodiversity (e.g., the Countryside Stewardship grants in the UK) (Rural Payments Agency and Natural England 2024). In addition to governmental schemes, charity and industry-driven incentives might offer financial support or expertise to farmers for habitat creation and environmental improvements, for example by WWF and Air Wick (2021), Royal Countryside Fund (2023) and National Lottery Heritage Fund (2023). Although agri-environmental schemes are designed for environmental benefits, some may pay for themselves in terms of yield and crop quality benefits or reduced production costs (Kleijn et al. 2019; Blaauw and Isaacs 2014). However, the cost:benefits of 'ecological intensification' are less often studied than the ecological effects (Kleijn et al. 2019). For ecological intensification, such as flower strips, a lack of scientific investigation and knowledge into financial benefits and direct or opportunity costs under a range of context-specific scenarios may be limiting the uptake of these methods by growers (Kleijn et al. 2019). As such, improved knowledge is needed on where, how much of, and what kind of flower strips should be implemented to achieve economic benefits.

Apple is a major crop that has been used to study the effects of flower strips both spatially and temporally (Senior et al. 2020; Howard et al. 2024). It is a high value crop and one of the most widely grown fruits in the world, with 93 million tonnes harvested globally in 2021 (Food and Agricultural Organization 2023). In the UK, 200,000 t of dessert apples were produced in 2020 (Defra 2020). In most temperate regions, such as the UK, apple orchards are highly manipulated and they receive repeated applications of insecticides (Simon et al. 2011).

A significant economic pest of apple is rosy apple aphid (*Dysaphis plantaginea* [Passerini]), which causes fruit deformation and reduction of fruit size (Blommers et al. 2004). Aphid infestations in commercial orchards are typically treated using insecticides (Dib et al. 2010; Penvern et al. 2010), and untreated orchards can incur losses of up to 80% (C. Schulz 2003, pers. comm. in Qubbaj et al. 2005). Flower strips can be used as a tool to sustainably aid *D. plantaginea* suppression up to 50 m into the crop area (Howard et al. 2024), although the economic costs and benefits of this method are unknown. The development of a bio-economic model, based on experimental results, is one method to determine the benefits and costs of flower strips for different years and spatial arrangements (Castro et al. 2018). To inform management decisions by land managers, it is critically important to understand the economic costs and benefits of different approaches, particularly over time.

The objective of this paper was to develop and use a bio-economic model to compare the establishment and opportunity costs of perennial wildflower strips at the border and centre of orchards with benefits derived from increased yields due to reduced *D. plantaginea* fruit damage. To account for inter-annual variation, we used experimental results from a year with lower levels of *D. plantaginea* infestation (25% of trees damaged), termed 'low infestation', and a year with higher levels (65% of trees had fruit damage), termed 'high infestation' (Howard et al. 2024). We then evaluated the financial costs and benefits of flower strips under three scenarios: (1) a flower strip on land which would otherwise be an extension of the standard grass headland, (2) a flower strip on cropland which could otherwise be used to produce apples and (3) a flower strip in the centre of an orchard. For scenario 3, data for flower strips bordering the orchards were extrapolated to explore the hypothetical scenario of a central flower strip.

2 | Methods

2.1 | Modelling Approach

We developed a spreadsheet model in Microsoft Excel describing the benefits and costs of a flower strip in an apple orchard. Biophysical data for the benefits and costs associated with perennial flower strips, and on the level of damage caused by *D. plantaginea* in apple orchards, were used to develop our bio-economic model (Howard et al. 2024). Data were generated from a 2-year study in 10 conventional UK commercial dessert apple orchards of the variety Gala in South-East England in 2021 and 2022. A full description of the study and sampling methods is described by Howard et al. (2024). Briefly, five orchards, termed as 'flower strip orchards' were bordered by an established sown perennial flower strip (2–5 years), and five 'control orchards' had only a permanent grass headland 4–5 m wide, typically mown four times a year (Figure 1). The average width of the flower strips was 15.3 m (SD = 9.6 m) (Howard et al. 2024, Table S1). All orchards were conventionally managed. Flower strip and control orchards were paired on the same farm so local landscape context and the use of pesticides, nutrients, and mowing were similar. A distance of 120–410 m was maintained between the orchards with flower strips and those without, minimising co-use by the same invertebrates and differences in soil type and aspect. Flower strips were sown with perennial flowering species and grasses designed to offer multiple flowering times and flower shapes, and to maximise pollen and nectar resources (details in Carvell et al. 2022). To encourage earlier flowering, and to keep weeds under control, all flower strips received no fertiliser or herbicide and they were cut to 8–10 cm annually in autumn, and the cuttings removed (Carvell et al. 2022). To measure effects of the flower strips on pest control and crop production in 2021 and 2022, apples per tree were recorded at 0, 5, 10, 20, and 50 m

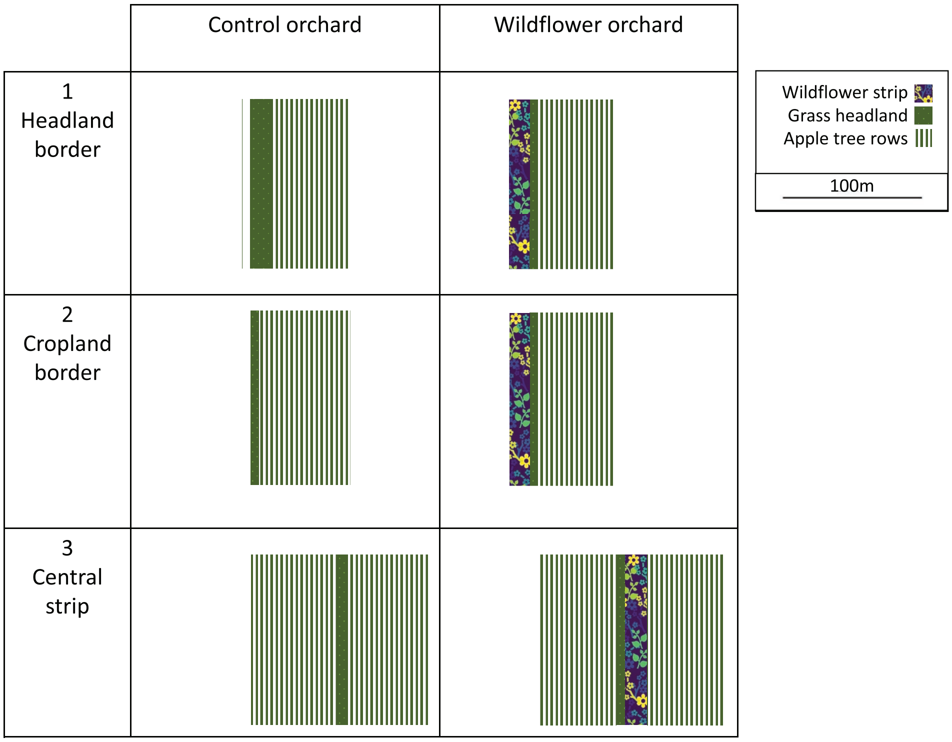

FIGURE 1 | Illustration of the orchard area represented by the financial model under three scenarios: (1) Headland border where the flower strip was established on a grass headland, (2) Cropland border where the flower strip was established on cropland and (3) Central strip where the flower strip was established on cropland in the centre of an orchard.

from the orchard edge along three transects in each orchard (45 trees per orchard). Then the proportion of fruit damaged by *D. plantaginea* was recorded on the same trees. At harvest, fruit damaged by *D. plantaginea* was identified by extremely reduced size and malformed shape, often with puckering around the calix, to the degree that the fruit was unmarketable. Class 2 fruit were considered undamaged.

2.2 | Data Inputs

2.2.1 | Biophysical Parameters of the Study Area

Within the bio-economic model we set a sample plot size of about 1 ha ($21.1\,\mathrm{m}+55.0\,\mathrm{m}\times 124\,\mathrm{m}=9440\,\mathrm{m}^2$) which was based on the mean dimensions of the study areas in flower strip orchards described by Howard et al. (2024). The width of the flower strip and the grass headlands were set at 15.3 and 5.8 m respectively, and it was assumed that they run alongside an orchard that was 124 m long. To model the effect of distance from the edge of the orchard, the yields within the orchard were subdivided into five sub-plots comprising trees at distances of 0–2.5, 2.5–7.5, 7.5–15, 15–35 and 35–55 m from the flower strip (Table 1). In the field study, the data were collected up to 50 m into the orchard, so it was assumed that there was no additional pest control benefit of a flower strip beyond 55 m into the orchard. As such, the flower strip and control orchards were assumed to be the same past 55 m. Within each sub-plot distance, we assumed the same number of apples per tree between the wildflower and the control treatments (Table 1) and a uniform yield response to *D. plantaginea* within each sub-plot. Although the area covered in Scenario 3 ($21.1\,\mathrm{m}+110\,\mathrm{m}\times 124\,\mathrm{m}=16{,}260\,\mathrm{m}^2$) was greater than Scenario 1 and 2, all of the results were standardised to the net margin per hectare. For the financial model, the area of the sample is determined by Equation (1), where D is the distance from the edge of the orchard (m), W is the width of the sample (m), and A_s is the area of the sample (m^2).

$$A_s = D\,W \tag{1}$$

2.2.2 | Yield and Fruit Damage Data

A financial analysis was completed for each year, 2021, which had a high incidence of *D. plantaginea*, and 2022, which had a low incidence (Howard et al. 2024). The inclusion of a flower strip reduced the proportion of fruit loss in both years, but whereas the level of damage was reduced from 11.94% to 3.97% in 2021 when incidence was high, the reduction was only from 1.33% to 1.00% in 2022 when incidence was lower (Table 1). For the statistical results see Howard et al. (2024). The severity of *D. plantaginea* infestation, and the level of fruit damage, can vary widely with apple variety (Razmjou et al. 2014), management (Porcel et al. 2018), weather, foliar nitrogen and tree age (Brown and Myers 2010), so infestation levels are all relative. The fresh mass of a Gala apple in the UK can vary between 0.12 and 0.16 kg so a mean mass of 0.14 kg was set for the analysis (The Basin Pantry: https://thebasinpantry.com.au/royal-gala/ Ukrainian food platform: https://ukrainian-food.com.ua/products/product/gala-apple).

TABLE 1 | Number of apples per tree and proportion of fruit lost recorded at different distances from the edge of the orchard in a year with low levels of infestation by *Dysaphis plantaginea* (2022), and high levels (2021) used in the bio-economic model.

	Low levels of infestation (2022)				High levels of infestation (2021)			
	Mean number of apples per tree		Proportion of fruit lost (%)		Number of apples per tree		Proportion of fruit lost (%)	
Distance from edge of orchard (m)	Without	With flower strip	Without	With flower strip	Without	With flower strip	Without	With flower strip
0–2.5	68	68	1.31	4.06	66	66	8.12	4.93
2.5–7.5	74	74	1.08	0.22	62	62	12.83	3.09
7.5–15	80	80	2.77	0.75	73	73	9.6	5.01
15–35	89	89	0.87	1.35	68	68	10.58	3.03
35–55	76	76	1.32	0.55	61	61	14.43	4.6
Mean[a]			1.33	1.00			11.94	3.97

[a]Weighted mean (proportional to sample area).

TABLE 2 | Assumptions regarding the establishment cost of a flower strip, the value of apples and grants for flower strips.

		Cost	Gain
Flower strip			
Establishment cost	Labour cost of creating flower strip (£/ha)	119.71	
	Wildflower seed cost (£/ha)	1024.92	
Annual cost	Cost of mowing grass once (£/ha/year)	28.20	
Annual subsidy	Countryside stewardship (£/ha/year)		673.00
Crop area			
Annual cost	All production costs (£/ha/year)	24,465.00	
Revenue	Wholesale price Gala apple 2021 (DEFRA) (£/kg)		1.01
	Wholesale price Gala apple 2022 (DEFRA) (£/kg)		1.06

2.2.3 | Financial Data

Within the financial analysis we calculated an establishment cost for creating the flower strips of £1145/ha which included the average costs of ploughing, shallow power harrowing, ring rolling, broadcasting and the cost of the wildflower seed (Table 2).

The annual maintenance costs were based on one mowing of the flower strips and four mowing events for a grass headland. An annual cost per mowing event of £28.20/ha was assumed based on the farmers' own labour, tractor and machinery fuel use, and repairs and depreciation (Redman 2020). The average annual costs associated with apple production included crop sundries (such as tree and stake replacement), harvesting (labour cost), grading and packaging, annual value of initial establishment costs, pruning and husbandry (Redman 2020). The default subsidy received for the flower strip was set as £673/ha/year (Rural Payments Agency and Natural England 2024) (Table 2). One of five flower strips was sown with a different perennial seed mix which had a lower cost. However, for simplicity, the model assumes that the same seed mix was used for all five strips (Table 2). The assumed mean wholesale price of Gala apples in the UK was £1.01/kg in 2021 and £1.06/kg in 2022 (Defra 2022) (Table 2). The loss due to aphids (L_a; £/m^2) is determined by Equation (2), where L_p is the proportion of apples lost due to aphids, F_m is the mean fresh mass of a fruit (kg/apple), N_t is the tree density (trees/m^2), T_a is the total apples per tree (apples/tree), and P_w is the average wholesale price (£/kg).

$$L_a = L_p\, F_m\, N_t\, T_a\; P_w \tag{2}$$

For each scenario (e.g., with and without flower strips), the total benefits (B_t), total costs (C_{total}), the net benefits (N_b) and the differences in net benefits (ΔN_b; £/m^2) were calculated to determine the financial impact of flower strips using Equations (3–6), where P_a is the average wholesale price per kilogram accounting for damage (£/kg), F_d is the fresh mass of fruits per square metre (kg/m^2), C_e is the equivalent annual value of establishment costs (£/m^2), C_m is the annual maintenance costs (£/m^2), B_t is the total benefit (£/m^2) and C_{total} is the total cost (£/m^2).

$$B_t = P_a\, F_d \tag{3}$$

$$C_{total} = C_e + C_m \tag{4}$$

$$N_b = B_t - C_{total} \tag{5}$$

$$\Delta N_b = N_{b\ \mathrm{Flower\ Strip}} - N_{b\ \mathrm{Control}} \tag{6}$$

The value of ΔN_b was then extrapolated to the total area under apple orchards (A_{total}) and combined apple and flower strip areas ($A_{apple+flower}$) to compare financial outcomes at scale (£).

2.2.4 | Temporal Aspects

To account for the opportunity cost to immobilising capital in long-term projects, future benefits and costs were reduced or 'discounted' using an approach developed by Faustmann (1849). To account for the upfront costs of establishment and the public preference for money now rather than later, we calculated the net present value (NPV; £/ha) of establishing the flower strip, where C is the cost in year t (£/ha), i is the discount rate, and t is the year from flower strip establishment to T, which is the assumed duration of the flower strip (Faustmann 1849; Equation 7).

$$\mathrm{NPV} = \sum_{t=0}^{t=T} \frac{C^t}{(1+i)^t} \tag{7}$$

Second, an equivalent annual value (EAV; £/ha/year) of establishing the flower strip was calculated using Equation (8) by multiplying the NPV from Equation (4) with a function of the discount rate i and the longevity of the flower strip, n (Table 2).

$$\mathrm{EAV} = i\,\mathrm{NPV}\frac{(1+i)^n}{(1+i)^n - 1} \tag{8}$$

For the analysis, we assumed a discount rate of 4%. Although this is lower than the time value of money indicated by most farmers, it is similar to the discount rate of 3.5% used by the UK Government in cost–benefit analysis (HM Treasury 2023).

The longevity of perennial flower strips is uncertain (Brittain et al. 2022; Schmidt, Kirmer, et al. 2022; Fountain 2022) and will likely vary, for example with different seed mixes (Schmidt et al. 2020), or by location (Pfiffner et al. 2019) [e.g., due to natural weed pressures, and soil fertility (Schmidt et al. 2020), and management (Mateos-Fierro et al. 2021; Herz et al. 2019)]. Within the second year of the field study, four of the flower strips had been established for 5 years, and the fifth strip for 2 years, so assumed benefits of the flower strips for up to 25 years are speculative. Apple orchards themselves can remain in place for up to 25 years.

2.2.5 | Accounting for Variation in Apple Tree Density

The yield of apples from an apple orchard can vary with season, apple variety, the density of apple trees, and apple tree age and branch formation. Howard et al. (2024) reported that there were fewer apples per m^2 in the five study orchards on sites bounded by a flower strip than by a grass border, but this result was not statistically significant ($\chi^2 = 0.557$, df = 1, $p > 0.05$). Hence, in the financial analysis we have assumed that the number of apples per m^2 was the same in both the flower strip and the control orchards (Table 1). Within the area of apple trees, we assumed a consistent tree density of 0.24 trees per m^2 for both flower strip and control orchards (but see Tables S1 and S2 for details and results for actual apple density data from the sites). The assumed number of apples was greater in 2022 than in 2021 to reflect inter-annual variation recorded in the orchards (Table 1).

2.3 | Modelled Scenarios

2.3.1 | Examining the Effect of Flower Strip Location

There are management implications and variable costs associated with where flower plots are placed within orchards, and this may also result in different levels of pest control due to spillover extent of beneficial arthropods. Therefore, to examine the impact of the flower strip relative to a control, three spatial arrangement scenarios were considered (Figure 1). As stated, the flower border was 15.3 m wide, and the headland was 5.8 m wide.

- Scenario 1 comprised a flower strip established on unproductive land which could not be planted with apple trees (Headland border),
- Scenario 2 comprised a flower strip in an area which could be planted with apple trees (Cropland border),
- Scenario 3 comprised a flower strip in the centre of the orchard that could have been planted with apple (Central strip) (Figure 1).

Although the area covered in Scenario 3 was greater than that of Scenarios 1 and 2, all of the results were standardised to the net margin per hectare. For scenario 3, data for flower strips bordering the orchards were extrapolated to explore the hypothetical scenario of a central flower strip.

2.4 | Sensitivity Analysis

Across the scenarios we also tested the sensitivity of the equivalent annual value of a flower strip to both longevity of the flower strip (1–25 years), changes in the subsidy amount from 0% to 200% of the default value of £673/ha/year, and pest pressure levels (low to high). Production costs of dessert apples can vary, for example, with yield size, so we tested the sensitivity of the equivalent annual value of a flower strip to production costs (Redman 2020).

3 | Results

The equivalent annual value over 5 years of the cost of establishing the wildflower strips was £315/ha/year, and over 10 years was £154/ha/year, and over 25 years was £75/ha/year.

3.1 | Wildflower Strip on Headland (Scenario 1)

The yield benefits from the presence of the wildflower strip meant that in a year of low pest incidence, the return from the wildflower treatment was similar to the control (only increasing by +£15/ha/year) whereas in the year of high pest incidence, the predicted net margin of the wildflower treatment would increase by +£1152/ha/year. The mean benefit over the 2 years was +£583/ha/year (Table 3). The equivalent annual value differed by £271/ha/year between a subsidy of 0% and 200% (Figure 2). The equivalent annual value differed by £215/ha/year between a flower strip which lasts for 1 year and a strip which lasts for 25 years (Figure 2).

3.2 | Wildflower Strip Bordering Cropland (Scenario 2)

By contrast, planting wildflowers on land which could have been used for apple trees resulted in a reduction in net margin of −£210/ha/year in a year of low incidence (2022) and an increase

TABLE 3 | Calculated annual margins (based on revenue minus changes in marginal costs) of three scenarios for locating a flower strip; (1) Headland border, (2) Cropland border, (3) Central strip (for flower strips which last 5 years), including the added value when subsidy is considered.

		Calculated annual margin (revenue minus change in marginal costs) without subsidy (£/ha/year)			
Pest infestation levels	**Scenario**	**Flower strip orchard**	**Control orchard**	**Difference**	**Subsidy**
Low	(1) Headland border	1809	1794	15	136
Low	(2) Cropland border	1809	2019	−210	136
Low	(3) Central strip	2146	1594	552	79
High	(1) Headland border	−3115	−4267	1152	136
High	(2) Cropland border	−3115	−5785	2670	136
High	(3) Central strip	−3572	−6569	2997	79

Note: High pest infestation: 2021; low pest infestation: 2022.

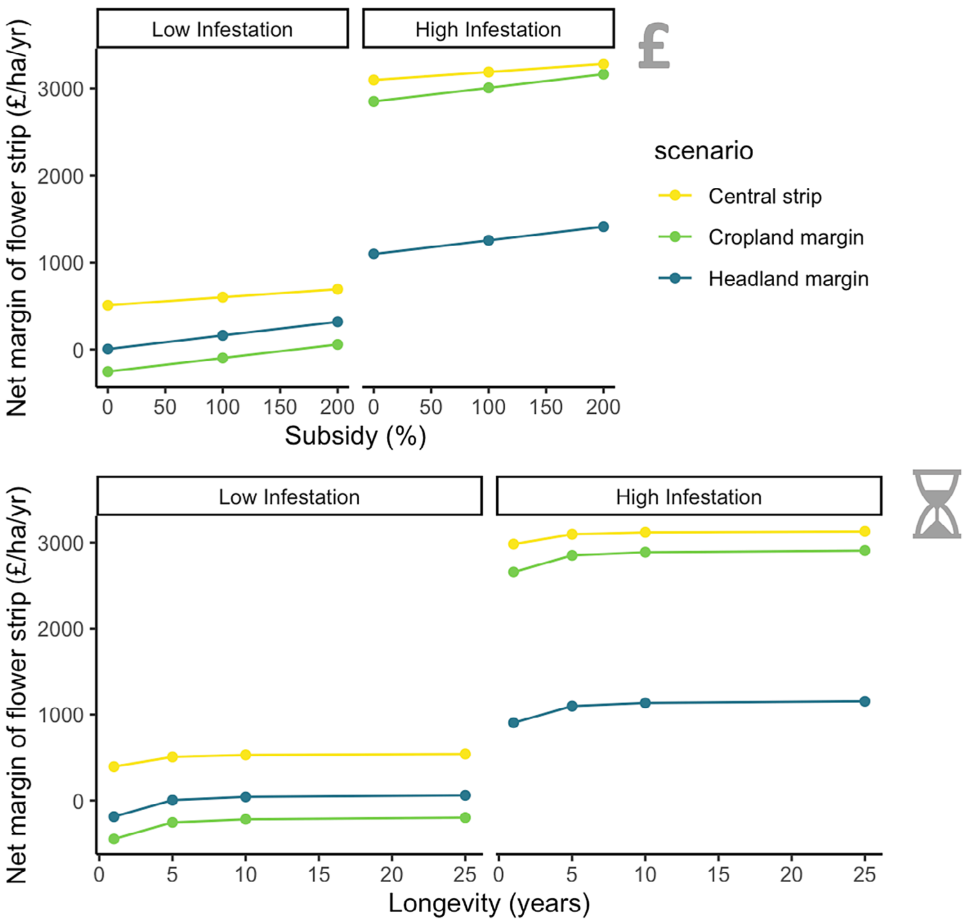

FIGURE 2 | Sensitivity of equivalent annual value of the net benefit of the presence of a flower strip according to subsidy amount (top) and longevity of the strip before resowing is required (bottom) (without subsidy), in a year with a low aphid infestation (2022, left), and high (2021, right), under three scenarios; (1) Headland border, (2) Cropland border, (3) Central strip. The default subsidy was £673/ha/year (Countryside Stewardship grant in the UK, 2021 and 2022 [Rural Payments Agency and Natural England 2024]).

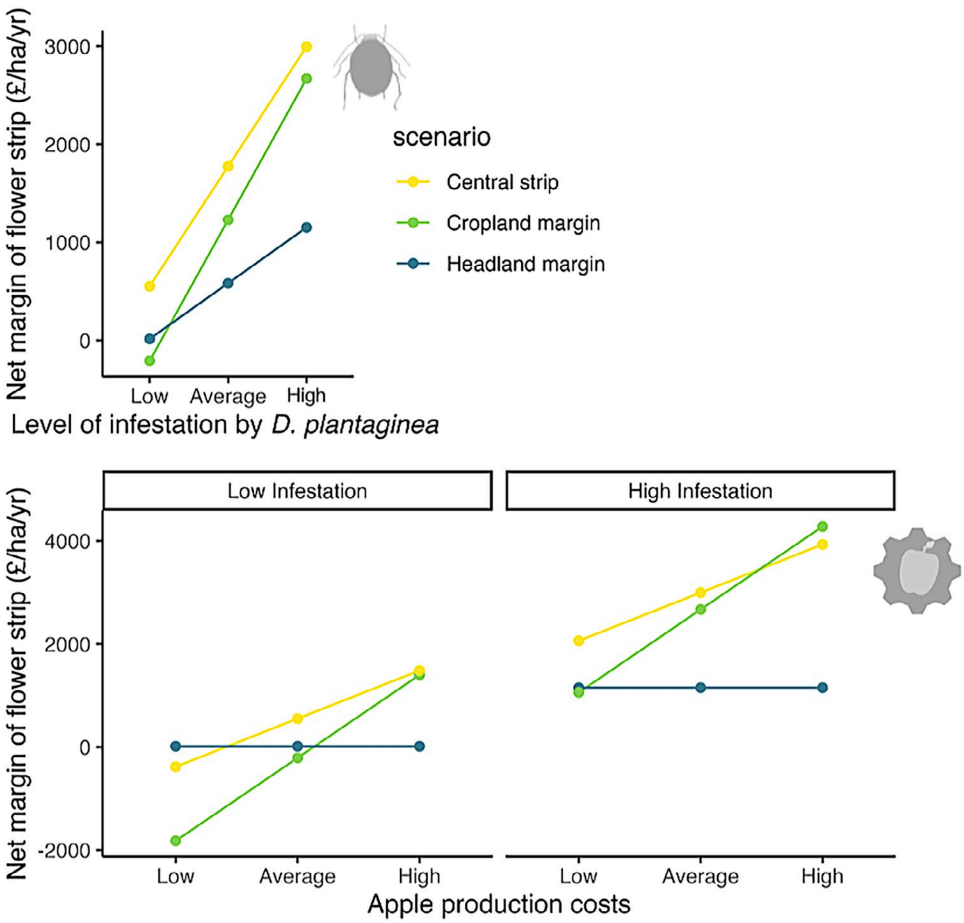

FIGURE 3 | Sensitivity of equivalent annual value of the net benefit of the presence of a flower strip according to level of pest infestation (top) and apple production costs (bottom) (default production costs = £24,465/ha/year); in a year with a low aphid infestation (2022, left), and high (2021, right), under three scenarios; (1) Headland border, (2) Cropland border, (3) Central strip (without subsidy and with flower strips which last 5 years before re-sowing).

in net margins equivalent to +£2670/ha/year in a year of high pest incidence (2021). The mean change in net margin was an increase of +£1230/ha/year (Table 3). The equivalent annual value differed by £271/ha/year between a subsidy of 0% and 200% (Figure 2). The equivalent annual value differed by £3219/ha/year between high and low apple production costs (Figure 3). The equivalent annual value differed by £215/ha/year between a flower strip which lasts for 1 year and a strip which lasts for 25 years (Figure 2).

3.3 | Wildflower Strip in the Centre of an Orchard (Scenario 3)

Data for flower strips bordering the orchards were extrapolated to explore the hypothetical scenario of a central flower strip. The modelled financial benefits of planting a wildflower strip in the centre of an orchard were calculated to be better than in Scenario 2 because the benefits of the wildflower strip were assumed to be effective in two directions, (i.e., on both sides of the strip). In a year of low pest incidence, the flower strip resulted in an increase in the net margin of +£552/ha/year. In a year of high pest incidence, the margin from the wildflower treatment was +£2997/ha/year more than in the control. The mean increase in net margin was +£1775/ha/year (Table 3). The equivalent annual value differed by £157/ha/year between a subsidy of 0%–200% (Figure 2). The equivalent annual value differed by £1869/ha/year between high and low apple production costs (Figure 3). The equivalent annual value differed by £125/ha/year between a flower strip which lasts for 1 year and a strip which lasts for 25 years (Figure 2).

4 | Discussion

4.1 | Flower Strip on Headland

The severity of the aphid infestation had a large effect on the change in net margin due to presence of a flower strip. In 2022, all our orchards had a low level of *D. plantaginea* infestation, but even then the flower borders 'paid for themselves' compared to standard primarily grass headlands. In 2021, there was a higher level of infestation by *D. plantaginea* in our orchards and flower borders provided significant financial benefits to growers by reducing *D. plantaginea* fruit damage compared to standard, primarily grass, headlands. When a subsidy (£673/ha/year) was taken into account, flower borders provided significant financial benefits to growers in both years (Rural Payments Agency and Natural England 2024). Such information surrounding the costs and benefits could encourage adoption of this pest control method by allowing farmers to evaluate the monetary value (Blaauw and Isaacs 2014; Ortega-Marcos et al. 2022). To our knowledge, ours is the first study to conduct a financial analysis of flower borders for pest control. Few studies have investigated the effect of flower borders on yield or monetary benefits of pest-control services in apple orchards (Herz et al. 2019; Kleijn et al. 2019; Fountain 2022), a trend observed across many crops (Crowther et al. 2023). A recent study by Jacobsen et al. (2022) found no impact of flower borders on the number of damaged apples compared to controls. Since Jacobsen et al. (2022) examined only 10 randomly selected apples per tree, perhaps this was not enough to identify statistical differences in fruit damage. By contrast, Howard et al. (2024) assessed all fruits on each of 450 trees (mean total apples per tree = 93, SD = 73) and found that in years of high infestation, only a low percentage of the total fruits were damaged in flower strip and control orchards (4% and 12%, respectively), and similar rates of damage in a year of low infestation (1% and 1%, respectively).

4.2 | Flower Strip on Cropland

The extent of financial benefits or costs of flower strips was context specific. We found that flower borders on cropland led to costs when the level of *D. plantaginea* infestation was low because the pest control benefits did not outweigh the opportunity costs. In that context, the subsidy would have needed to be £210/ha/year to offset the losses in the year when the aphid pest was less of a problem. However, during a year with high of *D. plantaginea* infestation levels, flower borders led to financial benefits to the growers even though the land could have otherwise been cropland.

4.3 | Central Flower Strips

Data for flower strips bordering the orchards were extrapolated to explore the hypothetical scenario of a central flower strip. Modelled flower strips in the centre of the orchard provided benefits in a year with low infestation due to the assumption that *D. plantaginea* pest control benefits would be experienced on both sides of the flower strip instead of only one side. Whilst this assumption is not evidenced, if those benefits were equal on both sides, during a year of high infestation, they led to similar financial benefits to the growers as did flower borders. The change in location of the strip, from the border to the centre, was enough to compensate for the opportunity costs. For crops generally, yield effects have been little studied and there are only a few examples of evidence that flower strips can lead to a sufficient increase in crop yield through ecosystem derived pest control services to cover both establishment and opportunity costs (pest control: Tschumi et al. 2016; pollination: Pywell et al. 2015). The assumed doubling of benefits from a central strip compared to a flower strip on headland or as a cropland border requires verification since it has yet to be tested in the field whether a flower strip of this size could support a sufficient increase in beneficial organisms to achieve this scale of impact.

4.4 | Sensitivity of the Net Margins

The net margins for flower strips on the headland showed lower levels of sensitivity to the change in the level of infestation by *D. plantaginea* compared to if flower strips replaced tree rows. This is because the opportunity costs were compensated for only when the pest control benefits were higher. Net margins of flower strips at different locations showed similar sensitivity to the longevity of the flower strips and the subsidy amount and showed much less sensitivity to these than to infestation levels and apple production costs. Apple production costs were estimated to range between £16,471/ha/year and £32,458/ha/year for 2021 (Redman 2020). This is not necessarily linked with differences in yield, although several post-harvest costs are relative to the number of apples marketed (Redman 2020). The net margin of the presence of both a flower strip on cropland and a strip in the centre of the orchard showed similar sensitivity to apple production costs, particularly during a year with high levels of *D. plantaginea* infestation, since the increased pest control benefits of a central strip somewhat compensated for the opportunity costs of a flower strip that replaces apple trees. Under low apple production costs, when *D. plantaginea* infestation was low and flower strips only lasted for 5 years, growers lost money for both cropland borders and central strips, whereas under average production costs, growers lost money only for cropland borders. The fruit damage benefits did not compensate for the opportunity costs, and apple production was less expensive. A benefit of a flower strip on the headland is that apple production costs have no effect on the net margin.

4.5 | Benefits of Flower Strips

In our study, we only considered the benefits of reduced *D. plantaginea* damage and subsidies. However, there are many other potential benefits of flower strips which could be included in future models. For example, control of other pests such as woolly apple aphid, tortricids, or codling moth (Bostanian et al. 2004; Fountain 2022) which are increasingly problematic due to the withdrawal and increasing restrictions on pesticide use (Frelih-Larsen et al. 2023). Additionally, there are ecosystem service benefits such as carbon sequestration (Harbo et al. 2022), pollination (Blaauw and Isaacs 2014; Morandin et al. 2016; Ortega-Marcos et al. 2022), and soil protection from flooding and erosion (Haddaway et al. 2018). Flower borders on headlands can be added to areas which would otherwise be unsuitable for apple trees, for example areas which temporarily flood, or are infertile, rocky, or impractical in shape. Flower borders could also potentially reduce the number of crop protection sprays required by reducing pest populations, and consequently reduce pesticide costs (e.g., Li et al. 2021). This could be investigated in future studies by working closely with agronomists to create custom integrated pest management programmes for each orchard where the application of aphicides would be a last resort. Currently, the threshold for an insecticide application to control *D. plantaginea* is one aphid per orchard (AHDB 2024).

There may also be non-monetary benefits of flower strips such as improvements to biodiversity (Haddaway et al. 2018), conservation of wild and managed pollinator species (Ortega-Marcos et al. 2022), support for farmland birds (Schmidt, Fartmann, et al. 2022), and landscape aesthetics and public perception (Uyttenbroeck et al. 2016). If a full cost–benefit analysis were to consider these wider societal benefits, these might outweigh the opportunity costs associated with a cropland flower strip when pest control benefits are less evident. The price of seed mix for establishing sown flower strips can vary (Schmidt et al. 2020), but since the establishment costs made little difference to the equivalent annual value of the flower strips when longevity varied (number of years they last before resowing), this was less important than the location of the flower strips and the level of infestation by *D. plantaginea*. Due to the interannual variation in infestation levels by *D. plantaginea*, the equivalent annual value of flower strips can also vary inter-annually, meaning the pest control benefits cannot be expected to be consistent across the life of the orchard. However, the benefits of flower strips might become more consistent if wider benefits were also considered. Pesticide withdrawals are leaving fruit growers with fewer effective products (Cressey 2017), hence the growing importance of sustainable tools for pest suppression.

4.6 | Alleyway Plantings

Alleyway plantings between rows of orchard trees are an alternative spatial arrangement for flower strips in orchards which do not result in opportunity costs (Staton et al. 2021). On average, these would each be approximately 23% the size of the flower strips used in our study since the alleyway in the United Kingdom (UK) is typically 3–4 m wide, although they would cover a greater overall area as there would be multiple strips. As such it may not be accurate to assume that the spatial effect of these flower strips on *D. plantaginea* fruit damage to be the same as that of a 15.3 m wide flower strip, and for this reason alleyway strips were not included in the financial model. However, they should be the focus of future studies with data on the effects of alleyway strips on pest control. Few studies have considered the effects of alleyway plantings on fruit damage, and those few which did have often found no effect on fruit damage by *D. plantaginea*, which could be due to pesticide use (McKerchar et al. 2020) or the use of newly established, rather than mature, strips (Campbell et al. 2017; Cahenzli et al. 2019; Howard et al. 2024; Herz et al. 2019). However, financial modelling by Staton et al. (2021) indicated that flowering perennial alleyway plantings increased farm income by £231 per ha of agroforestry compared with mown understories based on *D. plantaginea* damage to apples, mowing costs, and income from subsidy. The spill-over distance required would be smaller than for borders since the flowers are spread throughout the orchard which could improve efficiency in providing natural enemies for the crop. However, it must be noted that alleyway plantings can have logistical drawbacks such as domination by grasses in nutrient-rich soils (Pfiffner et al. 2019), competition for nutrients with very young orchard trees (Herz et al. 2019), and interference with farm machinery and activities (Rodríguez-Gasol et al. 2019; Ortega-Marcos et al. 2022; Mateos-Fierro et al. 2021).

4.7 | Effect of Orchard Variation

Although in a previous study the result was not statistically significant (Howard et al. 2024), the number of apples per meter squared was greater in the control orchards than the flower strip orchards. In our financial analysis we have assumed that the number of apples per meter squared was the same in both the flower strip and the control orchards. The number of apples produced by an orchard can vary greatly with factors such as tree density, tree height, branch formation, and pollination deficits, and we expect that flower strips would have only affected the latter, probably in a positive way (Garratt et al. 2023). As such, we assumed a fixed apple density in the model to simplify and standardise the analysis of the potential financial benefits. Additionally, since our flower strips were 2–5 years old and studies suggest that older borders may be more effective (Herz et al. 2019), it must also be considered that the borders could have been less profitable in the first year after re-sowing. These results could differ across countries since UK orchards may not be representative of orchards globally. For example, apple varieties grown in the UK will often differ to those grown elsewhere in the world. Similarly, agricultural landscapes in the UK may differ from other growing regions of the world, which could influence the effects of flower strips in promoting pest control (Karp et al. 2018). For example, in the UK, orchards are often found in relatively heterogeneous landscapes including semi-natural habitat and other crop-types. This is in contrast to some other countries that grow apples in larger plantations (Hassan et al. 2020). Our model could be applied using data from other countries and collected over a longer term.

4.8 | Conclusion

Flower strips provided significant financial benefits to growers by reducing fruit damage by *D. plantaginea* compared to standard headlands, particularly in a year with high levels of *D. plantaginea* infestation. The net benefit of the flower strips was influenced more by their location within the orchard and apple production costs than the annual subsidy, establishment costs, or longevity of the flower strip. In a year with low infestation by *D. plantaginea*, our study suggests that flower strips on the headland could be a positive financial investment. If non-crop land were not available, establishment of a flower strip in the centre of an orchard could offset most opportunity costs while also providing yield benefits during years with high *D. plantaginea* infestation. In a year with high infestation, our model indicated that apple production became unprofitable due to reduced yields and a high proportion of unmarketable fruits. While our results demonstrate that flower strips can provide financial benefits to growers by reducing pest damage, further information is needed on their additional benefits, such as enhanced pollination, biodiversity conservation, and contributions to climate change mitigation and adaptation, to fully assess their societal costs and benefits. This could help to guide policy for future flower-rich plots and subsidy amounts.

Author Contributions

Charlotte Howard: conceptualisation, formal analysis, writing – original draft, visualisation. **Paul J. Burgess:** conceptualisation, writing

– review and editing, funding acquisition. **Michelle T. Fountain:** conceptualisation, writing – review and editing, funding acquisition. **Claire Brittain:** conceptualisation, writing – review and editing, funding acquisition. **Michael P. D. Garratt:** conceptualisation, writing – review and editing, supervision, funding acquisition.

Acknowledgements

This work was financially supported by Syngenta and the Biotechnology and Biological Sciences Research Council (BBSRC), part of UK Research and Innovation (UKRI) with the FoodBioSystems Doctoral Training Partnership (FBSDTP) (BB/T008776/1). Thank you to the following for the establishment of the flower margins: UK Centre for Ecology & Hydrology (CEH) further supported by Avalon Produce, Worldwide Fruit, Syngenta and the Wildlife Farming Company. Thanks to the growers for the use of their sites. Thanks to Alison Lorenzo Cox and Georgieanna Brimblecombe for assistance with data collection (funded by the University of Reading's Undergraduate Research Opportunities Programme).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data available from the University of Reading Research Data Archive.

References

AHDB. 2024. "Apple Best Practice Guide." Accessed April 22, 2024. https://www.niab.com/monitoring-rosy-apple-aphid.

Blaauw, B. R., and R. Isaacs. 2012. "Larger Wildflower Plantings Increase Natural Enemy Density, Diversity, and Biological Control of Sentinel Prey, Without Increasing Herbivore Density." *Ecological Entomology* 37: 386–394.

Blaauw, B. R., and R. Isaacs. 2014. "Flower Plantings Increase Wild Bee Abundance and the Pollination Services Provided to a Pollination-Dependent Crop." *Journal of Applied Ecology* 51: 890–898.

Blommers, L. H. M., H. H. M. Helsen, and F. Vaal. 2004. "Life History Data of the Rosy Apple Aphid *Dysaphis plantaginea* (Pass.) (Homopt., Aphididae) on Plantain and as Migrant to Apple." *Journal of Pest Science* 77, no. 3: 155–163. https://doi.org/10.1007/s10340-004-0046-5.

Bostanian, N., H. Goulet, J. O'hara, L. Masner, and G. Racette. 2004. "Towards Insecticide Free Apple Orchards: Flowering Plants to Attract Beneficial Arthropods." *Biocontrol Science and Technology* 14, no. 1: 25–37. https://doi.org/10.1080/09583150310001606570.

Brittain, C., S. Benke, R. Pecze, S. G. Potts, F. J. Peris-Felipo, and V. P. Vasileiadis. 2022. "Flower Margins: Attractiveness Over Time for Different Pollinator Groups." *Landscape* 11: 1933.

Brown, A., and J. H. Myers. 2010. "Temporal and Spatial Variability of Rosy Apple Aphid *Dysaphis plantaginea* Populations: Is There a Role of the Alternate Host Plant *Plantago major*?" *Agricultural and Forest Entomology* 12, no. 4: 333–341. https://doi.org/10.1111/j.1461-9563.2010.00477.x.

Cahenzli, F., L. Pfiffner, and C. Daniel. 2017. "Reduced Crop Damage by Self-Regulation of Aphids in an Ecologically Enriched, Insecticide-Free Apple Orchard." *Agronomy for Sustainable Development* 37: 65.

Cahenzli, F., L. Sigsgaard, C. Daniel, et al. 2019. "Perennial Flower Strips for Pest Control in Organic Apple Orchards-A Pan-European Study." *Agriculture, Ecosystems & Environment* 278: 43–53.

Campbell, A. J., A. Wilby, P. Sutton, and F. Wäckers. 2017. "Getting More Power From Your Flowers: Multi-Functional Flower Strips Enhance Pollinators and Pest Control Agents in Apple Orchards." *Insects* 8, no. 3: 101. https://doi.org/10.3390/insects8030101.

Carvell, C., N. Mitschunas, R. McDonald, et al. 2022. "Establishment and Management of Wildflower Areas for Insect Pollinators in Commercial Orchards." *Basic and Applied Ecology* 58: 2–14.

Castro, L. M., F. Härtl, S. Ochoa, B. Calvas, L. Izquierdo, and T. Knoke. 2018. "Integrated Bio-Economic Models as Tools to Support Land-Use Decision Making: A Review of Potential and Limitations." *Journal of Bioeconomics* 20: 183–211.

Cressey, D. 2017. "The Bitter Battle Over the World's Most Popular Insecticides." *Nature News* 551, no. 7679: 156–158. https://doi.org/10.1038/551156a.

Crowther, L. I., K. Wilson, and A. Wilby. 2023. "The Impact of Field Margins on Biological Pest Control: Testing the Effects of Margin Type, Development Mode and Feeding Specialism via Meta-Analysis." *BioControl* 68, no. 4: 387–396.

Dainese, M., E. A. Martin, M. A. Aizen, et al. 2019. "A Global Synthesis Reveals Biodiversity-Mediated Benefits for Crop Production." *Science Advances* 5: eaax0121.

Defra. 2020. "National Statistics." https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwji1rC1iu_yAhUz_rsIHeACBiEQFnoECAIQAQ&url=https%3A%2F%2Fassets.publishing.service.gov.uk%2Fgovernment%2Fuploads%2Fsystem%2Fuploads%2Fattachment_data%2Ffile%2F1010175%2Fhort-dataset-11aug21.ods&usg=AOvVaw2WqPEjBja-GtQF1yQR1YP3.

Defra. 2022. "National Statistics, Wholesale Fruit and Vegetable Prices." https://www.gov.uk/government/statistical-data-sets/wholesale-fruit-and-vegetable-prices-weekly-average.

Dib, H., S. Simon, B. Sauphanor, and Y. Capowiez. 2010. "The Role of Natural Enemies on the Population Dynamics of the Rosy Apple Aphid, *Dysaphis plantaginea* Passerini (Hemiptera: Aphididae) in Organic Apple Orchards in South-Eastern France." *Biological Control* 55: 97–109.

Emmerson, M., M. B. Morales, J. J. Oñate, et al. 2016. "How Agricultural Intensification Affects Biodiversity and Ecosystem Services." *Advances in Ecological Research* 55: 43–97.

Faustmann, M. 1849. "Calculation of the Value Which Forestland and Immature Stands Possess for Forestry." *Journal of Forest Economics* 1, no. 1: 7–44.

Food and Agricultural Organization. 2023. "FAOstat Crops Production Data." https://www.statista.com/statistics/264001/worldwide-production-of-fruit-by-variety/.

Fountain, M. T. 2022. "Impacts of Wildflower Interventions on Beneficial Insects in Fruit Crops: A Review." *Insects* 13: 304.

Frelih-Larsen, A., C.-A. Chivers, I. Herb, J. Mills, and M. Reed. 2023. "The Role of Public Consultations in Decision-Making on Future Agricultural Pesticide Use: Insights From European Union's Farm to Fork Strategy Public Consultation." *Journal of Environmental Policy & Planning* 25: 476–492.

Garratt, M. P., R. S. O'Connor, C. Carvell, et al. 2023. "Addressing Pollination Deficits in Orchard Crops Through Habitat Management for Wild Pollinators." *Ecological Applications* 33, no. 1: e2743. https://doi.org/10.1002/eap.2743.

Haddaway, N. R., C. Brown, J. Eales, et al. 2018. "The Multifunctional Roles of Vegetated Strips Around and Within Agricultural Fields." *Environmental Evidence* 7, no. 1: 1–43. https://doi.org/10.1186/s13750-018-0126-2.

Harbo, L. S., G. Schulz, H. Heinemann, R. Dechow, and C. Poeplau. 2022. "Flower Strips as a Carbon Sequestration Measure in Temperate Croplands." *Plant and Soil* 482: 1–17.

Hassan, B., M. Bhattacharjee, and S. Wani. 2020. "Economics of High-Density Apple Orchards: A Comparative Analysis of Jammu and Kashmir, India and Trentino-Alto-Adige, Italy." *Global Journal of Human Social Science* 20, no. 9: 27–36.

Herz, A., F. Cahenzli, S. Penvern, L. Pfiffner, M. Tasin, and L. Sigsgaard. 2019. “Managing Floral Resources in Apple Orchards for Pest Control: Ideas, Experiences and Future Directions.” *Insects* 10, no. 8: 240. https://doi.org/10.3390/insects10080247.

HM Treasury. 2023. “The Green Book.” https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-government/the-green-book-2020.

Howard, C., M. T. Fountain, C. Brittain, P. J. Burgess, and M. P. Garratt. 2024. “Perennial Flower Margins Reduce Orchard Fruit Damage by Rosy Apple Aphid, *Dysaphis plantaginea* (Homoptera: Aphididae).” *Journal of Applied Ecology* 61, no. 4: 821–835. https://doi.org/10.1111/1365-2664.14598.

Jacobsen, S. K., H. Sørensen, and L. Sigsgaard. 2022. “Perennial Flower Strips in Apple Orchards Promote Natural Enemies in Their Proximity.” *Crop Protection* 156: 105962. https://doi.org/10.1016/j.cropro.2022.105962.

Judt, C., D. Korányi, J. G. Zaller, and P. Batáry. 2023. “Floral Resources and Ground Covers Promote Natural Enemies but Not Pest Insects in Apple Orchards: A Global Meta-Analysis.” *Science of the Total Environment* 903: 166139. https://doi.org/10.1016/j.scitotenv.2023.166139.

Karp, D. S., R. Chaplin-Kramer, T. D. Meehan, et al. 2018. “Crop Pests and Predators Exhibit Inconsistent Responses to Surrounding Landscape Composition.” *Proceedings of the National Academy of Sciences* 115, no. 33: E7863–E7870. https://doi.org/10.1073/pnas.1800042115.

Karp, D. S., H. V. Moeller, and L. O. Frishkoff. 2013. “Nonrandom Extinction Patterns Can Modulate Pest Control Service Decline.” *Ecological Applications* 23: 840–849.

Kleijn, D., R. Bommarco, T. P. Fijen, et al. 2019. “Ecological Intensification: Bridging the Gap Between Science and Practice.” *Trends in Ecology & Evolution* 34, no. 2: 154–166. https://doi.org/10.1016/j.tree.2018.11.002.

Li, S., C. C. Jaworski, S. Hatt, F. Zhang, N. Desneux, and S. Wang. 2021. “Flower Strips Adjacent to Greenhouses Help Reduce Pest Populations and Insecticide Applications Inside Organic Commercial Greenhouses.” *Journal of Pest Science* 94: 679–689.

Mateos-Fierro, Z., M. T. Fountain, M. P. D. Garratt, K. Ashbrook, and D. B. Westbury. 2021. “Active Management of Wildflower Strips in Commercial Sweet Cherry Orchards Enhances Natural Enemies and Pest Regulation Services.” *Agriculture Ecosystems & Environment* 317: 9.

McKerchar, M., S. G. Potts, M. T. Fountain, M. P. D. Garratt, and D. B. Westbury. 2020. “The Potential for Wildflower Interventions to Enhance Natural Enemies and Pollinators in Commercial Apple Orchards Is Limited by Other Management Practices.” *Agriculture, Ecosystems & Environment* 301: 107034.

Morandin, L., R. Long, and C. Kremen. 2016. “Pest Control and Pollination Cost–Benefit Analysis of Hedgerow Restoration in a Simplified Agricultural Landscape.” *Journal of Economic Entomology* 109, no. 3: 1020–1027. https://doi.org/10.1093/jee/tow086.

National Lottery Heritage Fund. 2023. “Local Places for Nature Capital Fund.” Accessed March 14, 2024. https://www.heritagefund.org.uk/funding/local-places-nature.

Oerke, E. 2006. “Crop Losses to Pests.” *Journal of Agricultural Science* 144, no. 1: 31–43. https://doi.org/10.1017/S0021859605005708.

Ortega-Marcos, J., V. Hevia, A. P. Garcia-Nieto, and J. A. Gonzalez. 2022. “Installing Flower Strips to Promote Pollinators in Simplified Agricultural Landscapes: Comprehensive Viability Assessment in Sunflower Fields.” *Landscape* 11: 1720.

Penvern, S., S. Bellon, J. Fauriel, and B. Sauphanor. 2010. “Peach Orchard Protection Strategies and Aphid Communities: Towards an Integrated Agroecosystem Approach.” *Crop Protection* 29: 1148–1156.

Pfiffner, L., F. Cahenzli, B. Steinemann, et al. 2019. “Design, Implementation and Management of Perennial Flower Strips to Promote Functional Agrobiodiversity in Organic Apple Orchards: A Pan-European Study.” *Agriculture, Ecosystems & Environment* 278: 61–71.

Porcel, M., G. K. Andersson, J. Pålsson, and M. Tasin. 2018. “Organic Management in Apple Orchards: Higher Impacts on Biological Control Than on Pollination.” *Journal of Applied Ecology* 55, no. 6: 2779–2789. https://doi.org/10.1111/1365-2664.13247.

Pywell, R. F., M. S. Heard, B. A. Woodcock, et al. 2015. “Wildlife-Friendly Farming Increases Crop Yield: Evidence for Ecological Intensification.” *Proceedings of the Royal Society B: Biological Sciences* 282: 20151740.

Qubbaj, T., A. Reineke, and C. Zebitz. 2005. “Molecular Interactions Between Rosy Apple Aphids, *Dysaphis plantaginea*, and Resistant and Susceptible Cultivars of Its Primary Host *Malus domestica*.” *Entomologia Experimentalis et Applicata* 115, no. 1: 145–152. https://doi.org/10.1111/j.1570-7458.2005.00255.x.

Razmjou, J., M. Changizi, A. Golizadeh, H. Karbalaee Khiavi, S. A. A. Fathi, and L. Mottaghinia. 2014. “Evaluation of Resistance in Seven Apple Cultivars to Rosy Apple Aphid, *Dysaphis plantaginea* (Hemiptera: Aphididae) Under Greenhouse and Field Conditions.” *Journal of Crop Protection* 3: 173–180.

Redman, G. 2020. *The John Nix Pocketbook for Farm Management*. 51st ed. Agro Business Consultants Ltd.

Rodríguez-Gasol, N., J. Avilla, Y. Aparicio, et al. 2019. “The Contribution of Surrounding Margins in the Promotion of Natural Enemies in Mediterranean Apple Orchards.” *Insects* 10: 148.

Royal Countryside Fund. 2023. “Creating a Real Future for Rural Britain.” Accessed March 14, 2024. https://www.royalcountrysidefund.org.uk.

Rural Payments Agency and Natural England. 2024. “AB8: Flower-Rich Margins and Plots.” https://www.gov.uk/countryside-stewardship-grants/flower-rich-margins-and-plots-ab8.

Schmidt, A., T. Fartmann, K. Kiehl, A. Kirmer, and S. Tischew. 2022. “Effects of Perennial Wildflower Strips and Landscape Structure on Birds in Intensively Farmed Agricultural Landscapes.” *Basic and Applied Ecology* 58: 15–25.

Schmidt, A., A. Kirmer, N. Hellwig, K. Kiehl, and S. Tischew. 2022. “Evaluating CAP Wildflower Strips: High-Quality Seed Mixtures Significantly Improve Plant Diversity and Related Pollen and Nectar Resources.” *Journal of Applied Ecology* 59: 860–871.

Schmidt, A., A. Kirmer, K. Kiehl, and S. Tischew. 2020. “Seed Mixture Strongly Affects Species-Richness and Quality of Perennial Flower Strips on Fertile Soil.” *Basic and Applied Ecology* 42: 62–72.

Senior, V. L., L. C. Evans, S. R. Leather, T. H. Oliver, and K. L. Evans. 2020. “Phenological Responses in a Sycamore–Aphid–Parasitoid System and Consequences for Aphid Population Dynamics: A 20 Year Case Study.” *Global Change Biology* 26: 2814–2828.

Simon, S., J.-C. Bouvier, J.-F. Debras, and B. Sauphanor. 2011. “Biodiversity and Pest Management in Orchard Systems.” *Sustainable Agriculture* 2: 693–709.

Staton, T., R. Walters, J. Smith, T. Breeze, and R. Girling. 2021. “Management to Promote Flowering Understoreys Benefits Natural Enemy Diversity, Aphid Suppression and Income in an Agroforestry System.” *Agronomy* 11: 651.

Tschumi, M., M. Albrecht, J. Collatz, et al. 2016. “Tailored Flower Strips Promote Natural Enemy Biodiversity and Pest Control in Potato Crops.” *Journal of Applied Ecology* 53: 1169–1176.

Uyttenbroeck, R., S. Hatt, A. Paul, et al. 2016. “Pros and Cons of Flowers Strips for Farmers. A Review.” *Biotechnologie, Agronomie, Société et Environnement* 20: 225–235.

Woodcock, B., J. Bullock, M. McCracken, et al. 2016. "Spill-Over of Pest Control and Pollination Services Into Arable Crops." *Agriculture, Ecosystems & Environment* 231: 15–23. https://doi.org/10.1016/j.agee.2016.06.023.

WWF and Air Wick. 2021. "Let's Bring Nature Back With Wildflower Restoration." Accessed March 14, 2024. https://www.wwf.org.uk/wildflowers.

Wyss, E. 1995. "The Effects of Weed Strips on Aphids and Aphidophagous Predators in an Apple Orchard." *Entomologia Experimentalis et Applicata* 75: 43–49.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.