Institution: University of Worcester		
Unit of Assessment: 5 Biological Sciences		
Title of case study: Enhancing sustainable food production		
Period when the underpinning research was undertaken: 2012-2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Dr Duncan Westbury	Principal Lecturer in Ecology and Environmental Management	18/04/2011 - current
Dr Kate Ashbrook	Senior Lecturer in Biology	12/01/2015 - current
Period when the claimed impact occurred: 2013 – 2020		
Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact

Research conducted by Westbury and Ashbrook in commercial fruit orchards has contributed to the universal goal of producing more food sustainably. When wildflower strips are used to underpin fruit production, they enable a reduction in use of Plant Protection Products (PPPs), and deliver direct benefits for biodiversity and ecosystem services.

Our research has underpinned new recommendations for fruit growers, changing policy and practice:

- There is now a mandatory requirement for wildflower areas in all new UK Jazz apple orchards.
- Bespoke wildflower options for commercial fruit growing areas to be included in the new Environmental Land Management scheme, the cornerstone of the UK government's new agricultural policy.
- Actively managed wildflower strips now recommended by Berry Gardens Ltd for all UK cherry orchards
- The implementation of wildflower strips in Spanish citrus orchards has been recommended by two major producers and exporters

2. Underpinning research

The tree fruit sector is seeking to reduce its reliance on Plant Protection Products (PPPs). This is due to the associated environmental impacts of PPPs and consumers increasingly demanding food that is safe and sustainably produced. The continued withdrawal of many PPPs also means that growers need to find alternative approaches to manage crop pests.

Since 2012, the University of Worcester has been actively engaged in research underpinning the sustainable production of food through different approaches to Integrated Pest and Pollinator Management (IPPM). Focus has been primarily on the ecological intensification of commercial fruit orchards.

To enhance the sustainability of fruit production, research has focused on reducing the dependence of fruit growers on the use of PPPs and managed pollinators, by boosting crop pollinators and natural enemies using wildflower interventions. UW has worked closely with apple, cherry and orange growers to develop new approaches for enhancing the sustainability and resilience of their production systems.

In 2012, Westbury secured £37K from Waitrose & Partners and Fruition PO for a 3-yr study investigating the use of bespoke wildflower strips to deliver pollination and pest regulation services in modern dessert apple orchards. This was the first-time that both services had been studied simultaneously in this system. The study revealed direct benefits for hoverflies in orchards sown with wildflowers, which in turn supports a more resilient pest regulation and pollination service. The study also revealed that the potential for wildflower interventions to support sustainable production was masked by the continued use of PPPs [1], highlighting the need for growers to consider the types and frequency of pesticide sprays used if they are to maximise the delivery of ecosystem services. Pollination data obtained from this research were also used to investigate the economic benefits of different pollinator guilds for four important UK apple varieties [2], and in a modelling approach to reliably predict the abundance of pollinators in different agricultural landscapes [3].

With funding from 2016-2020, Westbury *et al*. further developed the use of wildflower strips in sweet cherry (UK) (£43K, from Waitrose & Partners and Berry Gardens Ltd) and sweet orange (Spain) (£47K, from Waitrose & Partners and Primafruit Ltd) orchards. Working with growers, this was the first-time bespoke wildflower strips had been investigated in these economically important crops. Furthermore, it was the first-time that wildflower strips had been deployed under plastic covers. The research developed novel approaches to wildflower strip management, instigating active cutting regimes throughout the growing season to increase the spill-over of natural enemies into the crop and make wildflower options more grower-friendly. The aim of these research programmes was to drive forward the use of wildflower interventions to underpin fruit production.

The research in cherry orchards demonstrated that bespoke wildflower strips can be successfully established under plastic covers and despite the continued use of PPPs, the abundance and diversity of pollinators and natural enemies was increased. Importantly, pollination and pest regulation services were greater in orchards with wildflower strips, especially when actively managed with regular cutting (a game-changer for the industry). This study demonstrated the potential for growers to reduce PPP inputs and, of equal importance, to increase cherry yields, through the adoption of wildflower strips.

In Spain, it is typical for alleyways between rows of orange trees to be left bare, or for growers to manage any spontaneous vegetation with regular cutting throughout the year. Our orange study was an international collaboration with the Valencian Institute of Agricultural Research (IVIA, Spain), which focusses on citrus research. This was the first-time that wildflower habitats have been established in citrus crops to specifically increase the abundance and diversity of natural enemies. The approach led to increased pest regulation services and demonstrated the potential for growers to reduce the use of PPPs.

3. References to the research

[1] McKerchar, M., Potts, S.G., Fountain, M.T., Garratt, M.P.D. & Westbury, D.B. (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. https://doi.org/10.1016/j.agee.2020.107034

[2] Garratt, M.P.D., Breeze, T.D., Boreux, V., Fountain, M.T., McKerchar, M., Webber, S.M., Coston, D.J., Jenner, N., Dean, R., Westbury, D.B., Biesmeijer, J.C. & Potts, S.G. (2016). Apple pollination: demand depends on variety and supply depends on pollinator identity. PloS one, 11. https://doi.org/10.1371/journal.pone.0153889

[3] Gardner, E., Breeze, T.D., Clough, Y., Baldock, K.C.R., Campbell, A., Garratt, M., Gillespie, M.A.K., Kunin, W.E., Mckerchar, M., Memmott, J., Potts, S.G., Senapathi, D., Stone, G.N., Wäckers, F., Westbury, D.B., Wilby, A. & Oliver, T.H. (2020). Reliably predicting pollinator abundance: challenges of calibrating process-based ecological models. Methods in Ecology and Evolution. 11, 1673-1689. https://doi.org/10.1111/2041-210X.13483

References 2 and 3 are returned in the unit's output submission.

4. Details of the impact

Our research has revealed that wildflower strips can underpin fruit production resulting in the potential for growers to reduce their reliance on PPPs, which, in turn, can boost the abundance and diversity of natural enemies of crop pests and crop pollinators. A reduction in PPP use has benefits for biodiversity, whilst an increased adoption of wildflower areas within the landscape can improve water and air quality, provide greater protection of agriculture soils, mitigate flooding, and contribute to net zero farming.

Jazz apples are currently the largest single planted club variety in the UK, they represent 4.5% of all apples sold in the UK and are expected to be 7.5% of the UK apple market within the next 5 years. From 2018, Fruition PO mandated that 10 – 15% of the orchard area in all new Jazz apple orchards in the UK, be established with wildflower strips [a]. The reach of this change will be significant given that there are currently 320ha of Jazz apple orchards within the UK with a further 80ha to be planted by 2022. 80ha of new Jazz orchards have already been established with wildflower strips since 2018 and at least seven Fruition PO growers have opted to retrospectively create wildflower strips in their existing Jazz orchards. This includes the UK's two largest top fruit producers (Mansfields and AC Goatham & Son). Discussions are underway in relation to this requirement being rolled out in other countries where Jazz apples are grown e.g. New Zealand, USA, Chile, South Africa, and Australia.

Berry Gardens Ltd have a 65% market share of British cherry production. Based on our research findings, the company have highlighted their support for the use of actively managed wildflower strips in commercial cherry orchards, advocating this practice with all their British growers [b]. Berry Gardens have noted the potential for this novel approach to be a game-changer for fruit growers by enhancing environmental sustainability and enabling progression towards sustainable food production.

Our research has also found that wildflower strips in alleyways between rows of fruit trees in Spanish orange orchards enables citrus growers to achieve a more sustainable approach to pest control. Two major Spanish citrus producers and exporters (Martinavarro and Vicente Giner) now recommend the implementation of wildflower strips in their orchards [c] [d], increasing the reach of our research beyond

the UK and contributing to an international drive to enhance the sustainability of food production.

Growers are key to the adoption of any changes to fruit production. The team have supported annual grower and supplier events (Waitrose & Partners Science Day 2013-2019). A Farm Walk with growers was held in Kent in 2016, attended by 20+ growers, then written up as an online blog by John Guest "English Apple Man"; (https://bit.ly/36LNA8T), who gets 2,000 hits a month to his website (40% from the USA). Following our research, Waitrose & Partners have highlighted the importance of wildflower strips and sustainable apple growing across the world (https://bit.ly/377eQPw). In the Netherlands (2018) this led to the development of tractor-mounted kit designed to save growers time and money by enabling the rapid sowing of wildflower strips in orchard alleyways (https://bit.ly/3jPmcus).

Dissemination plans in 2020 were prevented due to the Covid-19 pandemic. We were to run stakeholder events in sweet cherry (hosted by Lower Hope Cherries), and citrus, (hosted by IVIA in Spain). However, we were able to participate in an AHDB webinar "Enhancing beneficial insects in orchard crops" which was attended by more than 60 growers and agronomists and made available on the AHDB webpage (https://bit.ly/30NAi8d).

To support fruit growers to adopt wildflower strips in their orchards, Westbury has worked with Natural England to encourage changes to UK Government agri-environment policy. Originally, growers were not permitted to establish wildflower strips in areas travelled over by farm vehicles which prevented many from adopting this measure in orchards. However, communication directly with Natural England contributed to the inclusion of wildflower strips in bush orchards. Then, to maximise the impact of this practice, in 2020, Natural England invited Westbury to produce scientific guidance for top fruit and soft fruit growers on how to establish and manage wildflower areas in their orchards.

As the UK has now left the EU, a new Environmental Land Management (ELM) scheme will replace the Countryside Stewardship scheme. Natural England have now invited Westbury to develop new wildflower options for commercial fruit growers for inclusion in the ELM scheme. This will be the first-time that such options will be available specifically for commercial top fruit and soft fruit crops. Importantly, this will increase the number of fruit growers joining the ELM scheme and those engaging with new sustainable, practices [e]. Following communication with colleagues at Linking Environment And Farming (LEAF), the adoption of wildflower strips in orchards is now also permitted under their Marque farm assurance scheme. An article based on the research conducted at UW was published by LEAF (Bulletin Issue 13: Crop Health and Protection) and disseminated to 2,000+ LEAF members [f].

We have increased the reach of our research through the BEESPOKE project, (EU funded, North Sea Region Programme). Findings from research conducted in apple, cherry, and orange orchards have been used to provide land managers and policy makers with the expertise, tools and financial knowledge to create more sustainable and resilient agroecosystems by increasing levels of pollinators and crop pollination. The key output from this project was the production of a guide in 2020, which highlighted how growers could establish wildflower strips in cropped areas [g]. This guide is now available across the EU to growers and has been translated into Dutch and Flemish to maximise its reach.

5. Sources to corroborate the impact

[a] Letter from Tony Harding Technical Director at Worldwide Fruit Ltd.

[b] Letter from Richard Harnden, Director of Research and Development, Berry Gardens Ltd.

[c] Letter from Elena Tosca, Technical Director at Martinavarro

[d] Letter from Claudio Millan, Vicente Giner

[e] Letter from David Whiting, Senior Specialist - Arable and Grassland Agronomy, Chief Scientist Directorate, Natural England.

[f] Westbury, D.B. (2018) Enhancing ecosystem services in top fruit orchards. Integrated Farm Management Bulletin Issue 13: Crop Health and Protection.

[g] BEESPOKE Leaflet – How to successfully establish perennial wildflower areas