Supplementary Information for

On farm experience shape farmer knowledge, perceptions of pollinators and management practices

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Supplementary Material

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Supplementary References

Grower Survey (English)

Supplementary Methodology

General survey design

Within a facilitated workshop, all authors decided on the insect pollinated crops to focus this study on. One criterion was availability, *i.e.*, number of farmers in each country, and the other criteria were variation within the pollinator community of the crops and variation in their pollinator dependency, resulting in four crops: apple (*Malus domestica*), avocado (*Persea americana*), kiwifruit (*Actinidia deliciosa*) and oilseed rape (*Brassica napus* L. or OSR). The survey was then designed in English and was translated by the surveyors for each country and proofread by another independent person. Growers were contacted either personally (*e.g.* at grower workshops), via email, via standard mail or through an online platform, which was promoted in different ways. Growers received a letter of introduction in addition to the survey.

Literature review: flower visitor abundances per crop and country

To understand if farmer perceptions are linked to relative abundances of pollinators per crop and country, we performed a literature review. We included studies in which data could be grouped into the same seven functional pollinator groups as in the questionnaire (i.e. honey bees, bumble bees, other bees, flies, butterflies, beetles, other pollinators). For each country-crop combination, we aimed to identify one or more studies recording relative flower visitor abundance (see Supplementary Table 02). If several studies were found, the average relative abundance was calculated. If no suitable study from a target country was found, studies from neighbouring countries were used (see Supplementary Table 02). The only country-crop combination for which we could not identify a suitable study to match our survey data was Israel-Avocados and therefore this combination was excluded from following analyses. To link those with farmer perceptions, we calculated the median rating of pollinators per crop and country.

Pollination biology of crops investigated

1. Apple (*Malus domestica*)

Worldwide, apple is an economically important crop. In 2019, apple was cultivated on 4.7 million ha globally with a total harvest of 87 million tonnes (FAOSTAT, 2021). Apple is highly pollinator-dependent (Free, 1993) and, for successful fruit set, most apple varieties need a cross-compatible pollinizer cultivar (Delaplane and Mayer, 2000). As predominant pollinators for apple flowers, bees and hoverflies are mentioned (Delaplane and Mayer, 2000; Klein et al., 2007), with bees accounting for most of the pollination (Garratt et al., 2016).

2. Avocado (*Persea americana*)

The demand for avocados is growing steadily. While in 2000 2.8 million tonnes were produced worldwide, already in 2010 production reached 3.9 million tonnes and in 2019 7.2 million tonnes (FAOSTAT, 2021). In 2019, avocado was cultivated on 0.7 million ha globally (FAOSTAT, 2021). The pollination of avocados is complex due to its dichogamous flowering behaviour (Free, 1993). While in some parts of the world avocados can self-pollinate or the pollen transfer is mediated by wind, as found in the US (Davenport, 2019), in other areas insects are required for successful pollination (Ish-Am and Lahav, 2011). This difference might be a result of different climatic regimes (Davenport, 2019). In Mexico, its native range, flies were the most abundant flower visitors, followed by honey bees and wasps (Pérez-Balam et al., 2012).

3. Kiwifruit (*Actinidia deliciosa*)

In 2019, Kiwifruit was cultivated on 0.3 million ha and 4.3 million tonnes were harvested globally (FAOSTAT, 2021). Kiwifruit is a functionally dioecious vine, meaning that it has distinct male and female individuals. Sufficient pollen transfer from males to female plants is crucial for kiwifruit production (Sáez et al., 2019). In its native range, kiwifruit can be pollinated by insects and by wind (Craig et al., 1988), but the most common pollination strategy is artificial pollination since kiwifruits are not so attractive to bees due to their lack of nectar reward (Sáez et al., 2019).

4. Oilseed rape (*Brassica napus*)

Oilseed rape (OSR) was grown on 34 million ha and 70.5 million tonnes were harvested globally in 2019 (FAOSTAT, 2021). This mass-flowering crop is self-compatible, can be wind-pollinated but also benefits from pollination by insects (Stanley et al., 2013). As it produces large quantities of nectar, OSR is very attractive to insect pollinators (Williams et al., 1986). It has been shown that both bees and flies are effective pollinators of OSR (Phillips et al., 2018).

Table S1 | Study regions and data collection. Number of questionnaires per country.

Country	Surveyor	Contact information	Crop	Number of questionnaires
Australia	Brad Howlett; Megan Gee	brad.howlett@plantandfood.co.nz	Avocado	44
Belgium	Maxime Eeraerts	maxime.eeraerts@ugent.be	Apple	21
Germany	Julia Osterman	jul.osterman@gmail.com	Apple OSR	44 30
Guatemala	Patricia Landaverde-González	patylandavr@gmail.com	Avocado OSR	20 22
Israel	Omri Avrech; Yael Mandelik	yael.mandelik@mail.huji.ac.il	Apple Avocado	31 32
New Zealand	Brad Howlet; Megan Gee	brad.howlett@plantandfood.co.nz	Apple Avocado Kiwifruit	28 74 31
Mexico	Flor Itzel Trujillo-Elisea	fitrujillo@ecosur.edu.mx	Avocado	31
Poland	Aleksandra Langowska, Zbigniew Koltowski;	aleksandra.langowska@up.poznan.pl zbigniew.koltowski@inhort.pl	Apple OSR	32 35
Slovenia	Danilo Bevk	danilo.bevk@nib.si	Apple	30
Spain	Marcos Miñarro	mminarro@serida.org	Apple	30
United Kingdom (UK)	Lorna Cole; Michael P. D. Garratt; Brad Howlett	lorna.Cole@sruc.ac.uk m.p.garratt@reading.ac.uk	OSR	25

Table S2 | Flower visitor abundances in percentage per crop and country

Survey country farmers perception	Crop (common name)	Number	Data holder	Location of study on flower visitor abundance	Source
Australia	Avocado	1	unknown	Australia	(Vithanage, 1986)
		2	brad.howlett@plantandfood.co.nz	Australia	(Evans and Goodwin, 2011)
		3	brad.howlett@plantandfood.co.nz	Australia	(Willcox et al., 2019)
Belgium	Apple	1	muriel.quinet@uclouvain.be	Belgium	(Quinet et al., 2016)
Germany	Apple	1	jul.osterman@gmail.com	Germany	unpublished
	Oilseed rape	1	jul.osterman@gmail.com	Germany	unpublished
Guatemala	Avocado	1	unknown	Mexico	(Ish-Am et al., 1999)
		2	Quezada-Euan: qeuan@uady.m	Mexico	(Perez-Balam et al., 2012)
		3	qeuan@tunku.uady.mx	Mexico	(Can-Alonzo et al., 2005)
	Oilseed rape	1	rihannon.fiction@gmail.com	Mexico	(Escobedo-Kenefic, 2020)
Israel	Apple	1	yael.mandelik@mail.huji.ac.il	Israel	unpublished
New Zealand	Apple	1	unknown	New Zealand	(Palmer-Jones and Clinch, 196
	Avocado	1	brad.howlett@plantandfood.co.nz	New Zealand	(Read et al., 2017)
		2	brad.howlett@plantandfood.co.nz	New Zealand	(Evans and Goodwin, 2011)
	Kiwifruit	1	brad.howlett@plantandfood.co.nz	New Zealand	(Howlett et al., 2017)
Mexico	Avocado	1	unknown	Mexico	(Ish-Am et al., 1999)
		2	Quezada-Euan: qeuan@uady.m	Mexico	(Perez-Balam et al., 2012)
		3	qeuan@tunku.uady.mx	Mexico	(Can-Alonzo et al., 2005)
Poland	Apple	1	unknown	Poland	(Jabłoński et al., 1981)
		2	unknown	Poland	(Wilkaniec, 1990)
	Oilseed rape	1	jul.osterman@gmail.com	Germany	unpublished
Slovenia	Apple	1	danilo.bevk@nib.si	Slovenia	(Bevk, D, Prešern, J., Pislak, M
Spain	Apple	1	mminarro@serida.org	Spain	(Miñarro and García, 2018)
		2	unknown	Spain	(Vicens and Bosch, 2000)
United Kingdom (UK)	Oilseed rape	1	m.p.garratt@reading.ac.uk	UK	(Dainese et al., 2019)

Table S3 | Estimates and test statistics of the generalised linear models relating farmer knowledge of pollinator groups with their pollinator management practices.

Comparison	DF	χ2	*P*
Providing honey bee hives			
Honey bee score	1	23.09	**< 0.001**
Bumble bee score	1	1.57	0.211
Other bee score	1	0.75	0.386
Median non-bee score	1	0.04	0.834
Crop	3	4.55	0.208
Country	10	89.00	**< 0.001**
Organic	1	0.05	0.819
Providing bumble bee nests			
Honey bee score	1	0.25	0.799
Bumble bee score	1	11.48	**< 0.001**
Other bee score	1	3.34	0.067
Median non-bee score	1	1.78	0.183
Crop	3	16.54	**< 0.001**
Country	10	38.48	**< 0.001**
Organic	1	0.75	0.386
Providing other bees			
Honey bee score	1	0.01	0.924
Bumble bee score	1	0.00	0.972
Other bee score	1	4.56	**0.033**
Median non-bee score	1	0.00	0.945
Crop	3	18.95	**< 0.001**
Country	10	22.71	**0.012**
Organic	1	0.00	0.963

Table S4 | Estimates and test statistics of the generalised linear models relating farmer knowledge of pollinator groups with their on-farm pollinator friendly measures.

Comparison	**DF**	**$\chi 2$**	***P***
Floral strips establishment			
Honey bee score	1	0.622	0.430
Bumble bee score	1	0.086	0.769
Other bee score	1	0.425	0.514
Median non-bee score	1	13.994	**< 0.001**
Subsidies	1	83.378	**< 0.001**
Crop	3	2.434	0.487
Organic	1	0.011	0.916
Hedgerow management			
Honey bee score	1	1.210	0.271
Bumble bee score	1	3.014	0.082
Other bee score	1	0.033	0.856
Median non-bee score	1	2.696	0.101
Subsidies	1	10.294	**0.001**
Crop	3	10.665	**0.014**
Organic	1	1.327	0.249
Other pollinator friendly management			
Honey bee score	1	0.011	0.917
Bumble bee score	1	0.094	0.367
Other bee score	1	0.814	0.367
Median non-bee score	1	1.270	0.260
Country	10	52.086	**< 0.001**
Crop	3	0.702	0.873
Organic	1	1.717	0.190

Supplementary Figures

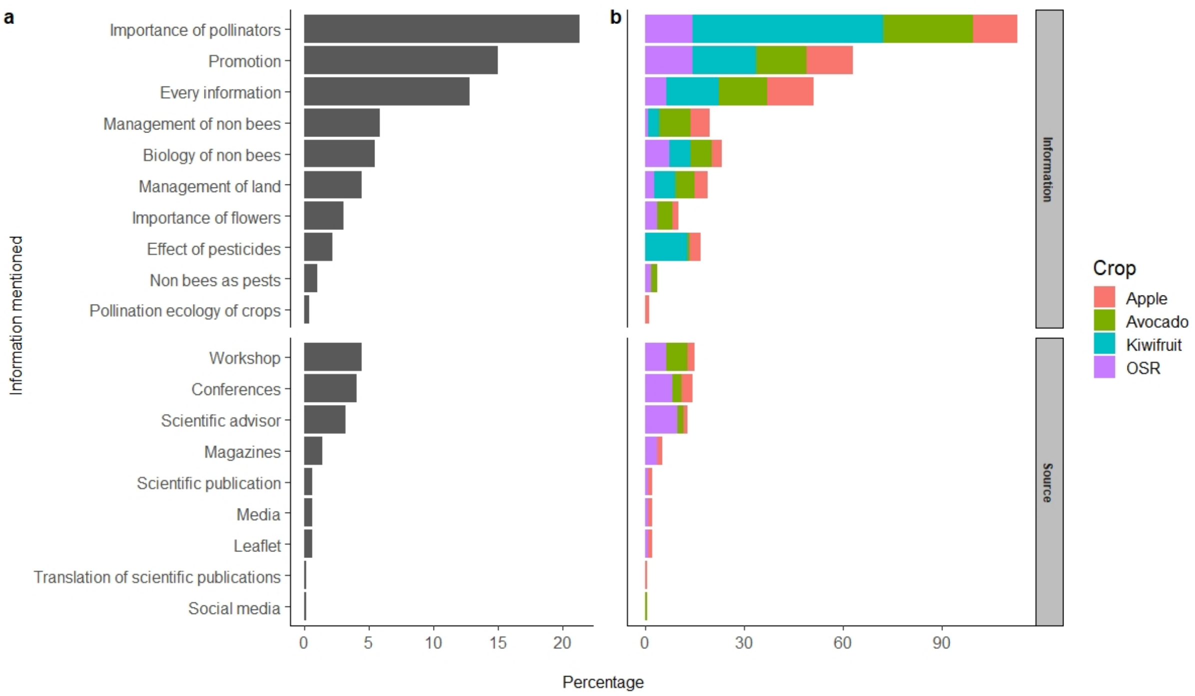

Fig. S1. Stated information and source of information wanted by farmers in regards to non-bees in overall percentage (a) and percentage per crop (b).

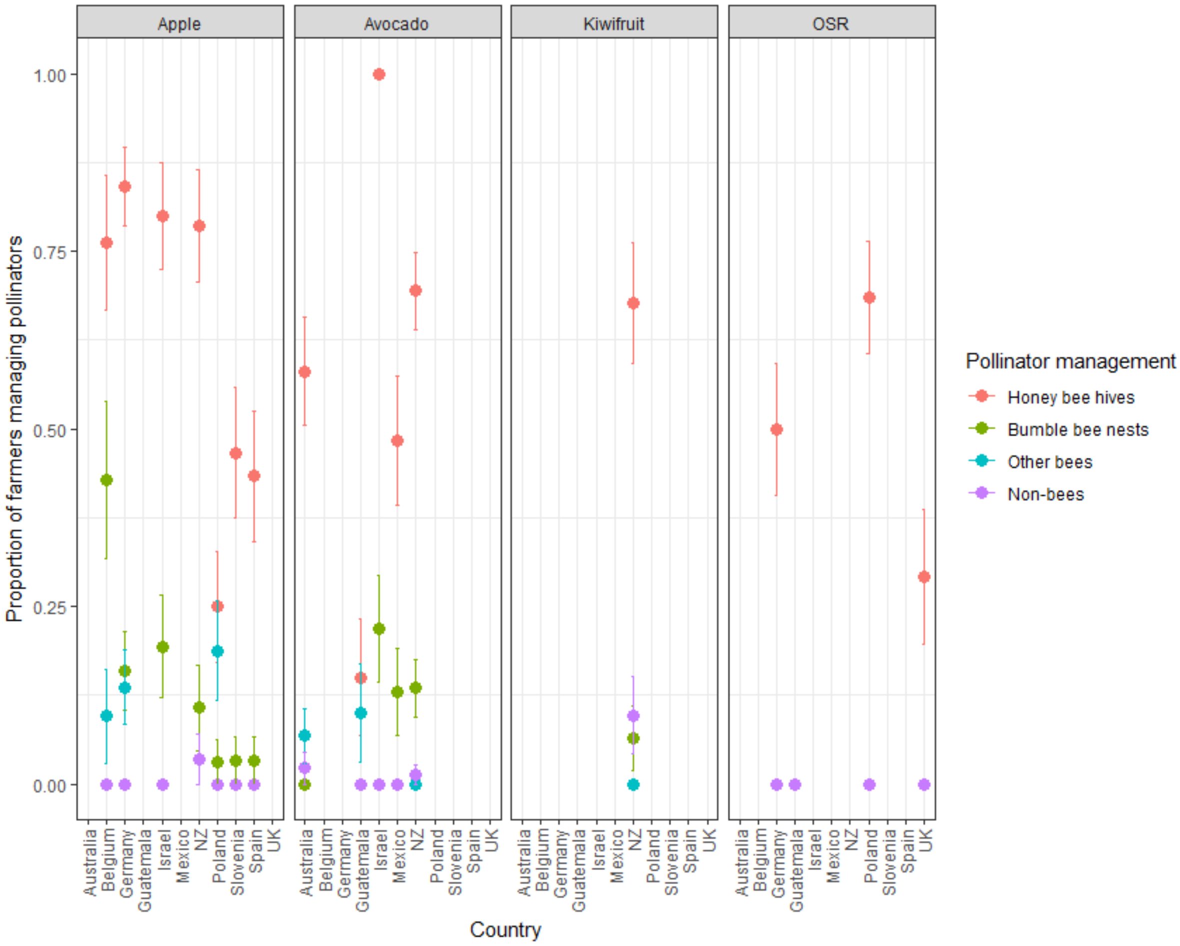

Fig. S2. Mean proportion of farmers managing pollinators per crop, country and management type. Error bars indicate ±1 SE.

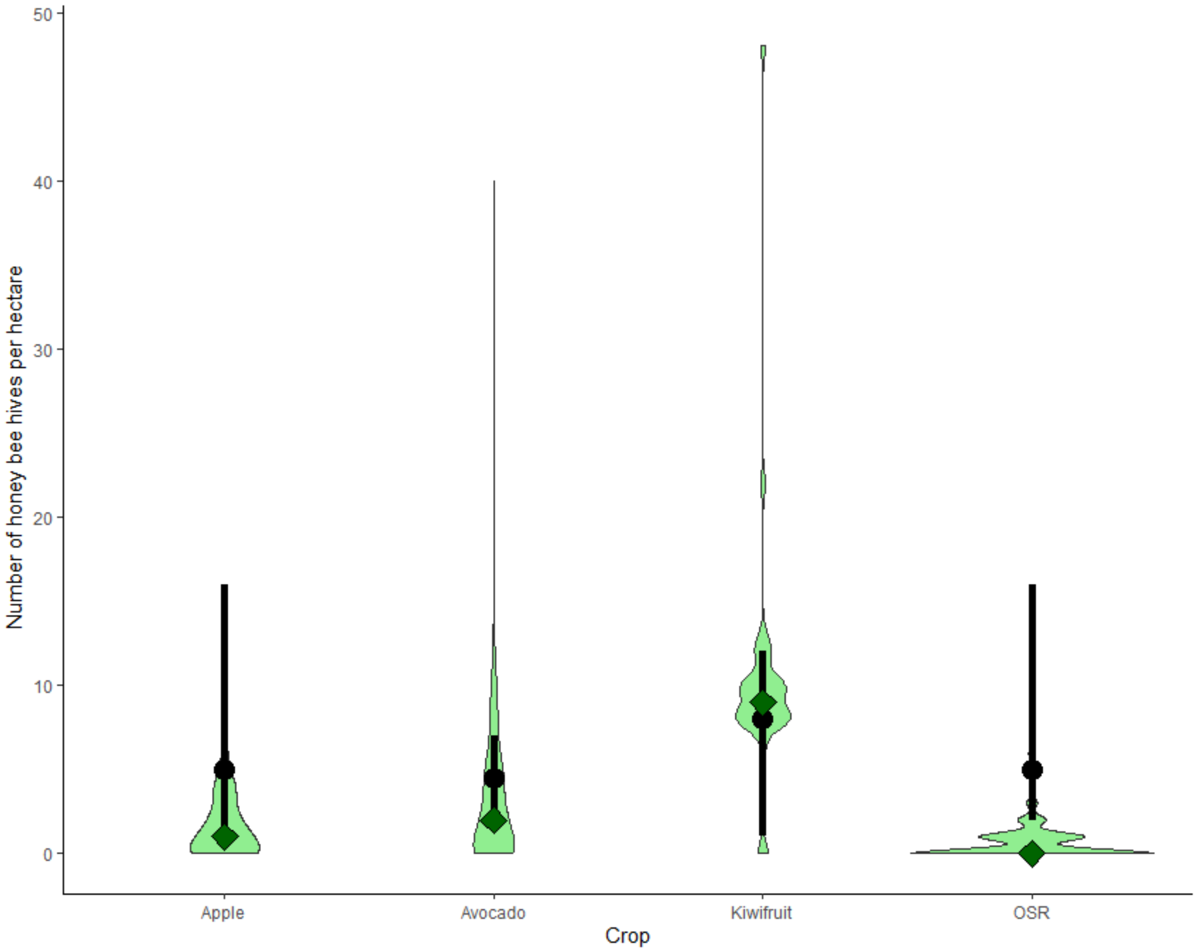

Fig. S3. Data distribution of number of honey bee hives per hectare according to crops (in light green, violin plot). Dark green diamonds represent the median hive number per hectare per crop. Black dots represent the mean number of hives and the black line the range of hives per hectare recommended by studies (reviewed in Rollin and Garibaldi, 2019).

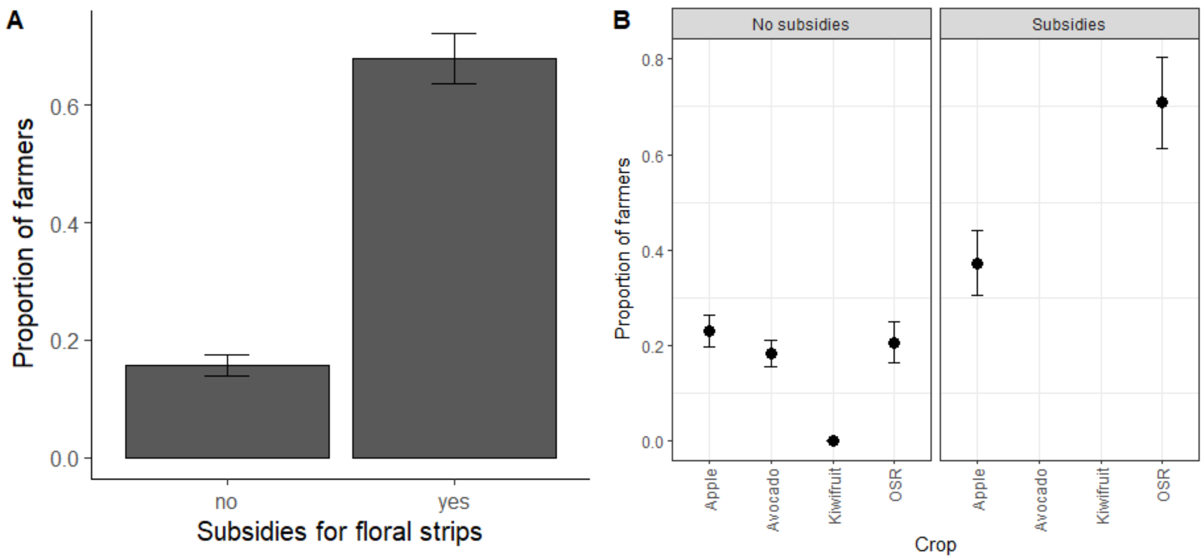

Fig. S4. Mean proportion of farmers implementing (A) floral strips with and without subsidies and (B) hedgerows depending on subsidies and crop type. Error bars indicate ±1 SE.

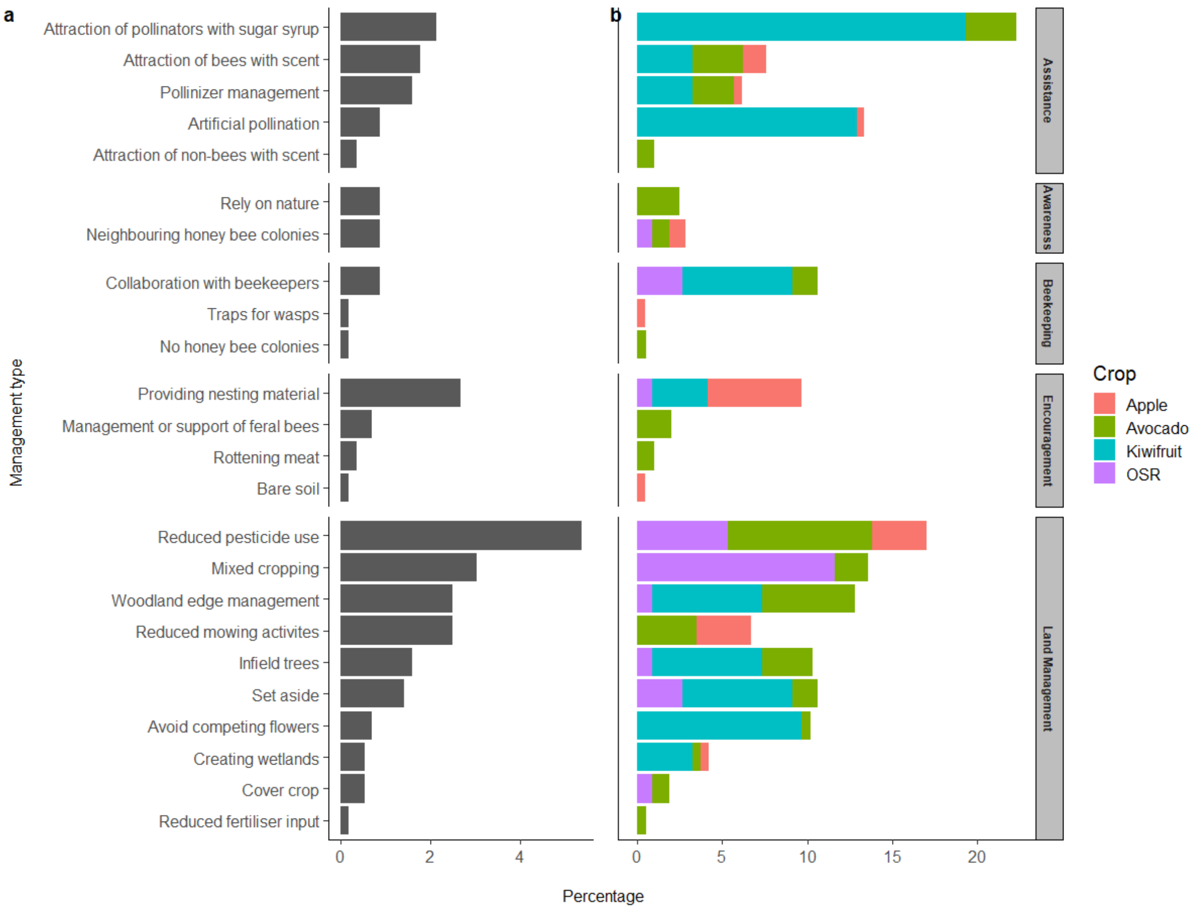

Fig. S5. Stated management types implemented to enhance biodiversity and pollination delivery by farmers (apart from floral strips and hedgerow management) in overall percentage (a) and percentage per crop (b).

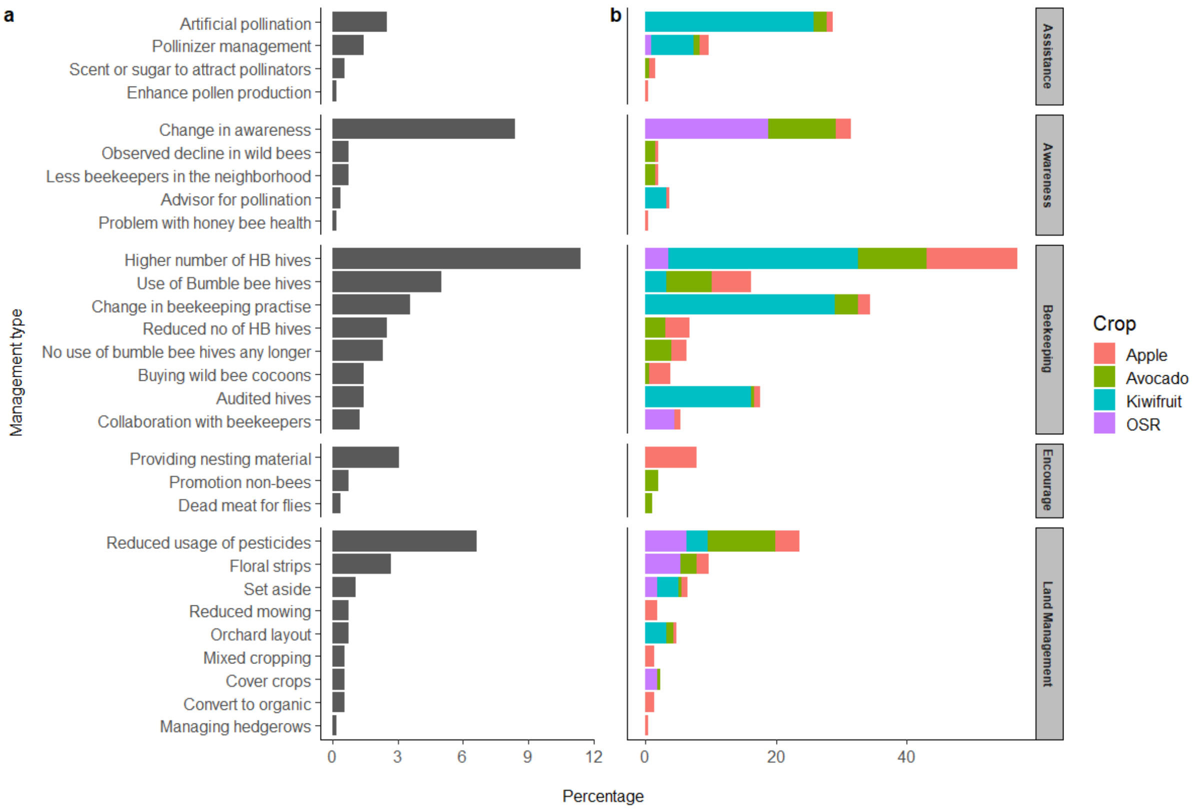

Fig. S6 | Stated changes in pollination management in the last 10 years by farmers in overall percentage (a) and percentage per crop (b).

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Grower Survey

Number Farm Crop Area (ha)

1) How many crops do you grow?

2) What crops do you grow that require insect pollination?
____

Please complete this for _________________ crop

Please specify

3) Are you certified Organic? Yes/No Please circle one

4) What is the overall area (ha) of your insect pollinated crop? _____________

5) How important are these pollinators for your crop? (score 0: if not at all, 1: if minor pollinators, 2: if somewhat important and 3: if very important)

Bees

Honeybees	0	1	2	3
Bumblebees	0	1	2	3
Other bees	0	1	2	3

Non-bees

Flies	0	1	2	3
Beetles	0	1	2	3
Moths/Butterflies	0	1	2	3
Others? Please specify	0	1	2	3

If you believe non-bees can pollinate your crop, please complete Q. 6-8 Otherwise please go to Q.9

6) Why are non-bee pollinators useful for your crop? Please tick

- they are more reliable pollinators than bees
- they visit my crop when bees aren't active
- they provide additional pollination above what bees can do

□ Other (please specify) ________________________________

7) What % do you think non-bees contribute to your crop yield? __________

8) How did you become aware that non-bees can contribute pollination to your crop? Please tick

I have seen them □

Other growers □

Farm advisor or agronomist □

Grower workshops □

Through grower resources (magazine, pamphlet) □

Other media (e.g. radio, tv, internet) □

Scientists (publications, discussions) □

Other (please specify) □

9) How do you manage or try to promote pollinators in your crop? Please tick

Provide floral strips for bees □ non-bees □

Manage hedgerows for bees □ non-bees □

Supply honeybees □ bumblebees □ other bees □ non-bees □

Other practices? Please specify ____

10) How many honeybees hives do you provide per /ha? ____ bumblebees /ha? ____ others (please specify) /ha? ____

11) Has your approach to pollination management changed in the last ten years? How?

____

____

12) Do you believe non-bee pollinators can play a more important role in your crop pollination in the future? Yes/No Please circle and explain why below:

____
_

____

13) What further information would you like to help you utilise non-bees better?i

____

____

About this survey

This study was initiated under the COST Super B programme, http://www.superb-project.eu/ and involves the collaboration of scientists from universities and research organisations across numerous countries including from Europe, Oceania and Africa.

The aim of this survey is to improve understanding of current crop grower knowledge regarding the diversity and value of pollinators within their crops. Growers will be surveyed across a number of countries to determine comparative knowledge and whether future strategies to improve pollination can be applied at a global scale. It will therefore provide information that can assist with future research priorities and determine whether scientific knowledge is being transferred adequately to growers.

We aim to publish the data alongside scientific knowledge and recommend strategies to improve the transfer of knowledge between growers and scientists. We will also aim to provide a summary of our findings to participating growers, should they request it (this data should be available by January 2019). By filling in the survey, participants consent to the collection and the usage of their data for the above described scientific purpose. Information gathered will be kept strictly confidential and any resulting publications will ensure participants can not be identified. Please contact us if you wish to withdraw your answers at any stage following survey completion. For this purpose you may wish to mark your survey with a code that you can easily refer to.

For further information about this survey and research please email either:

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