How to make biodiversity work for farmers
Examples from European flower margin projects

Felix Wäckers

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Entomologischer Verein Crefeld * 1905 *

PLOS ONE

RESEARCH ARTICLE

More than 75 percent decline over 27 years in total flying insect biomass in protected areas

The New York Times Magazine

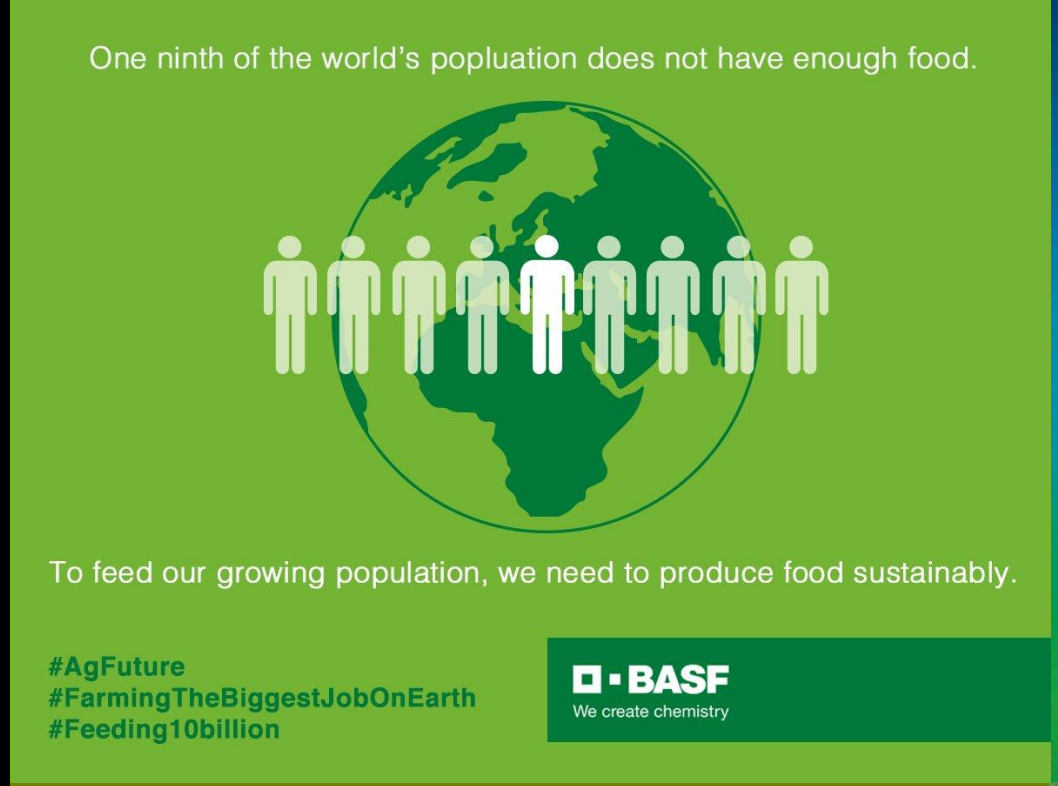
FEATURE

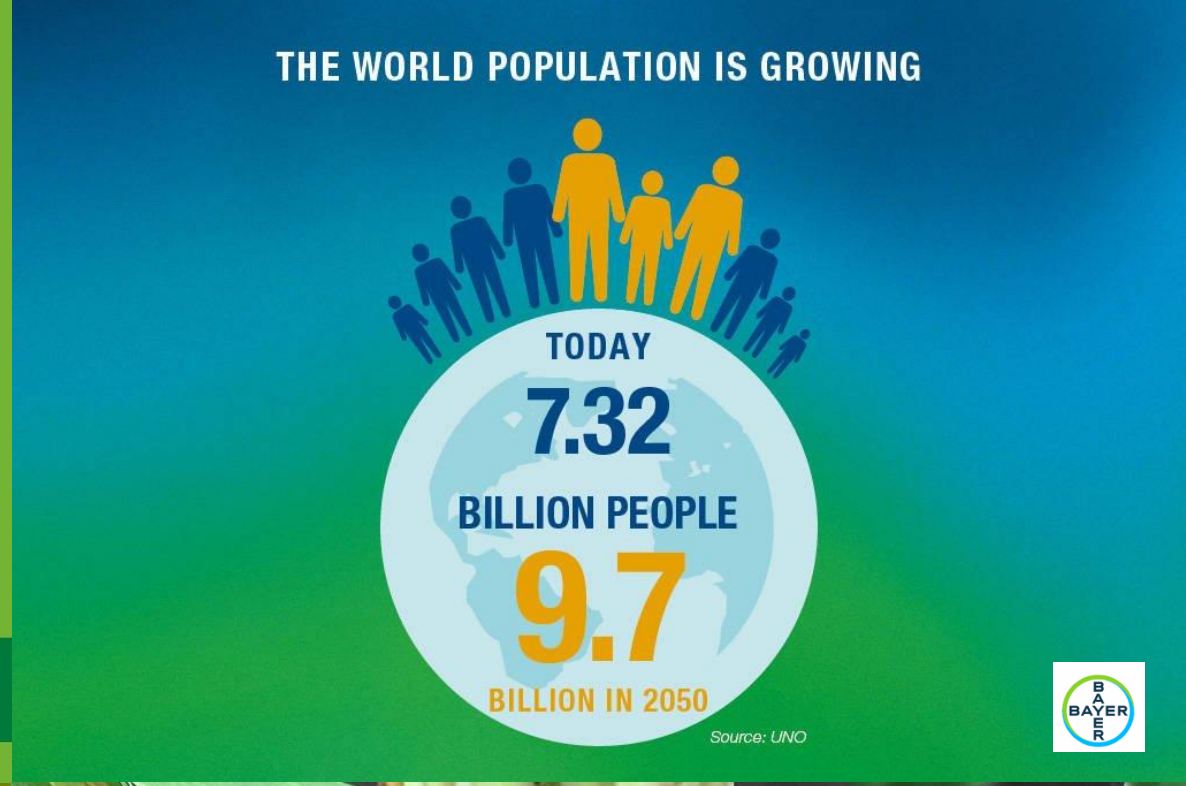
The Insect Apocalypse Is Here

What does it mean for the rest of life on Earth?

Intensive Agriculture as a driver of Biodiversity decline

The argument from the chemical industry





Land Sparing vs Land Sharing?


Yield or environment ?

By pitting **nature** against **farming**

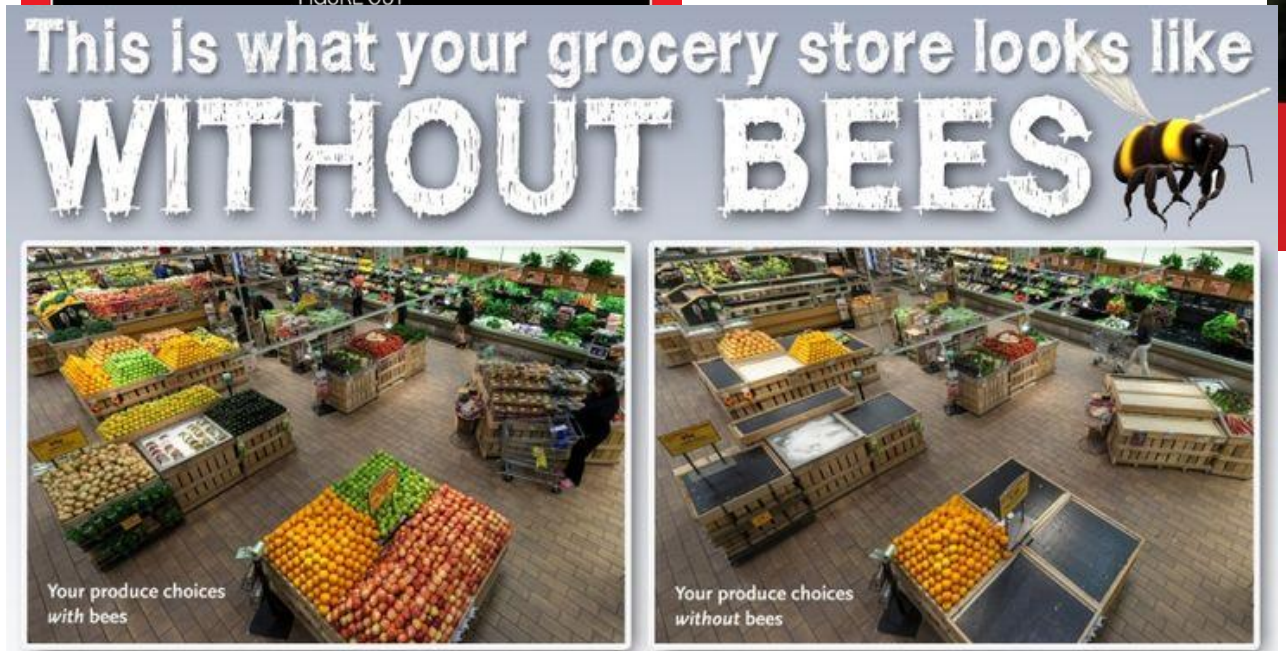
environment and yield are presented as conflicting objectives

...thus ignoring that nature and farming benefit each other

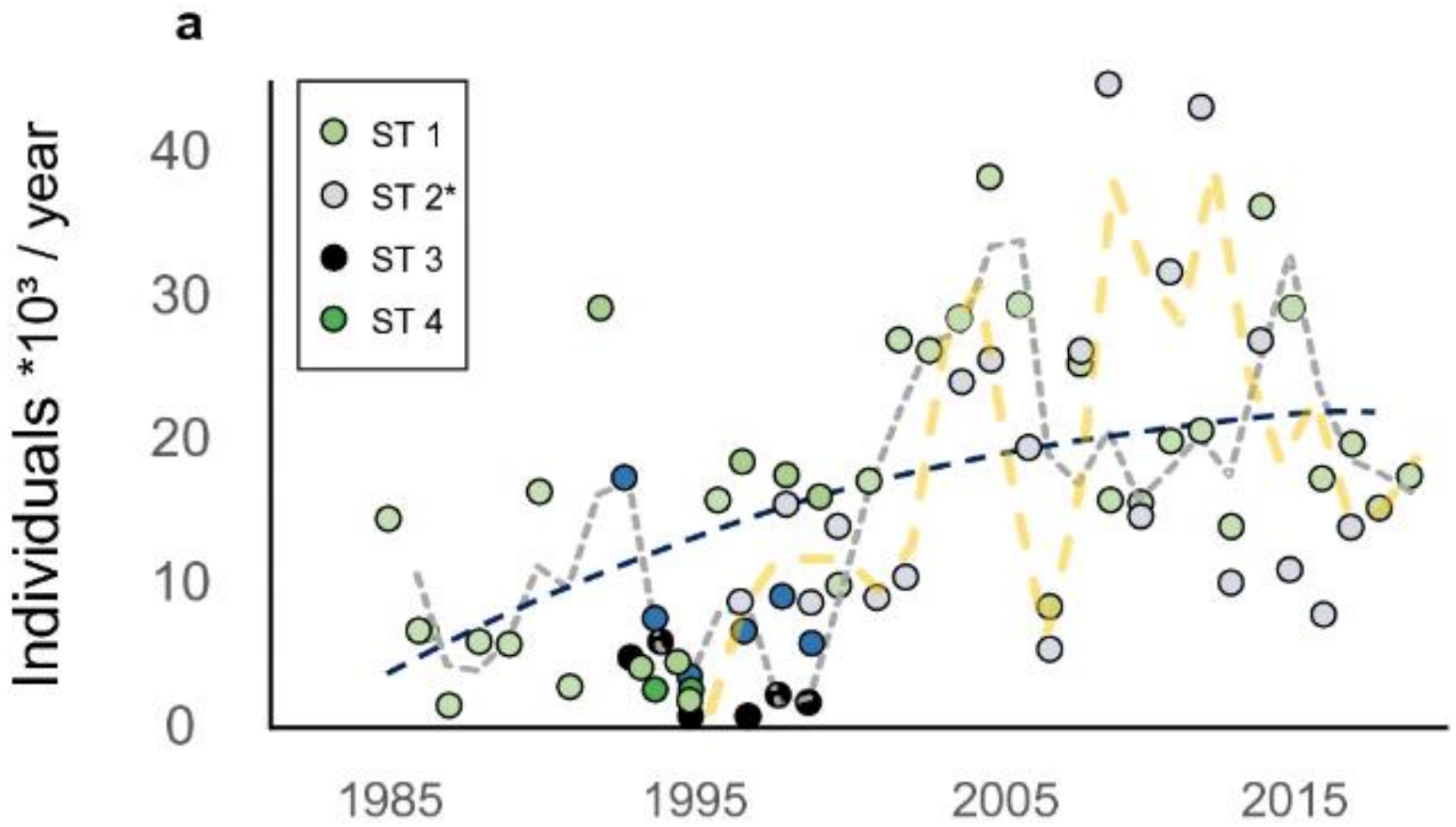
Nature ⟷ **Farming**

Ecosystem Services

Pesticides and insect decline also threaten crop production



Reduction in natural predators -> Increase in pest pressure?



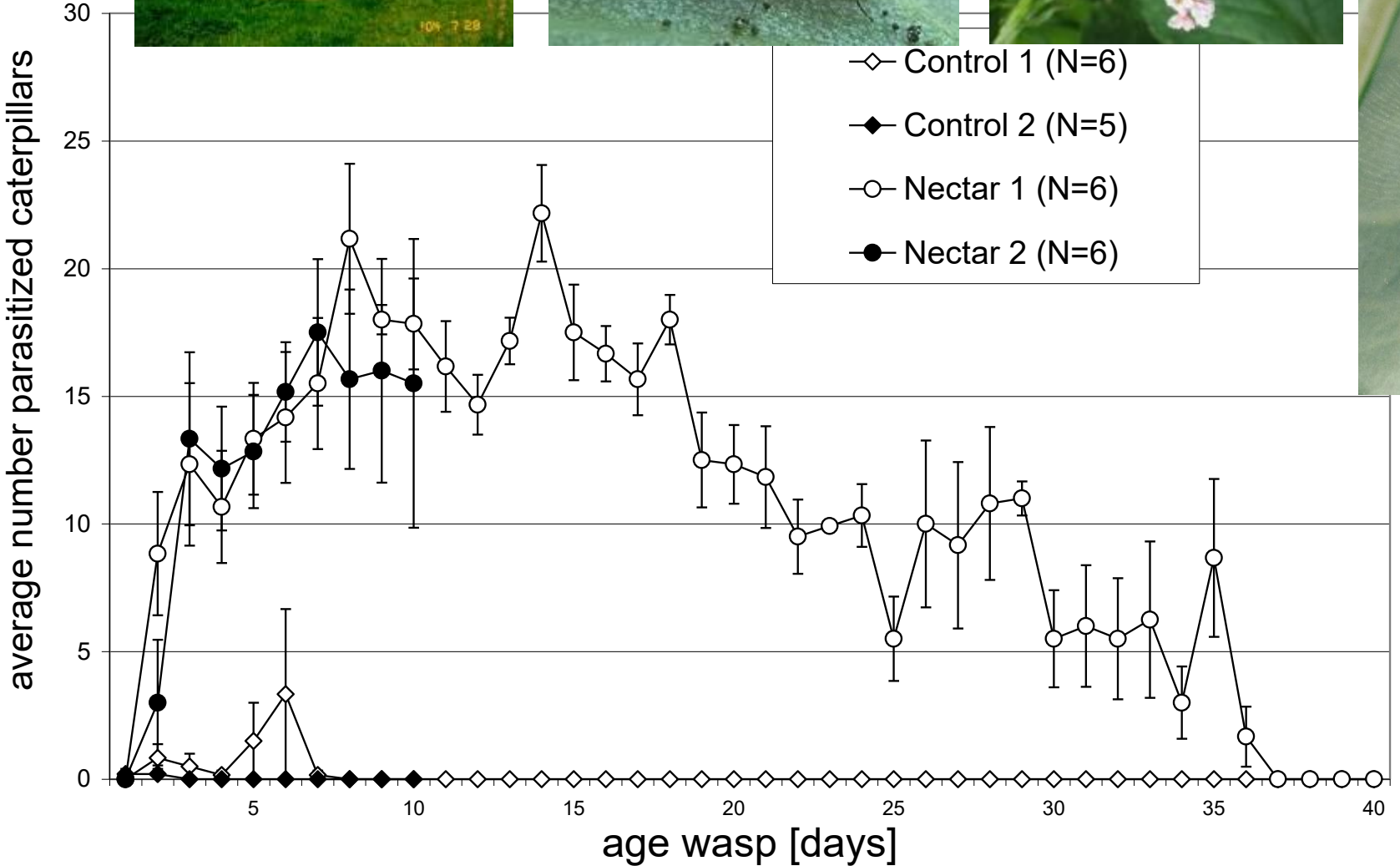
ZiescheTM et al, 2023, J. Pest Science

Flowers are vital for

Pollinators

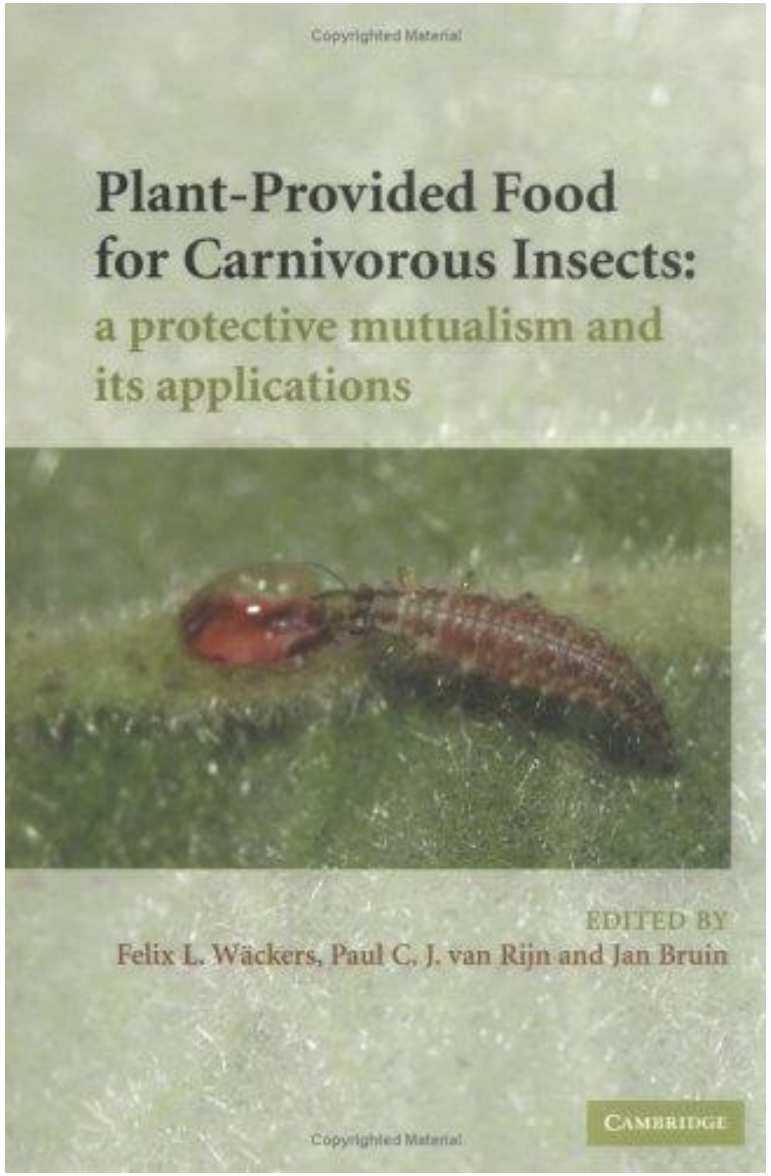
Insects providing natural pest control

The impact of flowers on biocontrol efficacy



Winkler et al., (2006)

Flower feeding by different groups of biocontrol organisms



Type	Plant-feeding stage	Arthropod examples can be found within:		Type of plant food utilised
Life-history omnivory	adult	Neuroptera: Diptera: Hymenoptera: Coleoptera:	Chrysopidae (green lacewings) Syrphidae (hoverflies) Cecidomyiidae (gall midges) Tachinidea (parasitoid flies) Ichneumonidae, Braconidae, a.o. (parasitoid wasps) Vespidae (social wasps) Formicidae (ants) Meloidae (blister beetles)	nectar, pollen nectar, pollen nectar nectar nectar nectar nectar, fruit nectar nectar, pollen
	juvenile	Heteroptera:	Pentatomidae (stink bugs)	plant-juice
Temporal omnivory	adult	Hymenoptera: Coleoptera:	Ichneumonidae, Braconidae, a.o. (host feeding parasitoids) Cicindelidae (tiger beetles)	nectar seeds
	juvenile	Araneae:	Araneidae (orb web spiders)	pollen
Permanent omnivory	adult & juvenile	Acari:Mesostigmat Heteroptera: Neuroptera: Thysanoptera: Coleoptera:	Phytoseiidae (predatory mites) Pentatomidae (stink bugs) Miridae (mirid bugs) Geocorinae (big-eyed bugs) Anthocoridae (flower bugs) *Chrysopa,* Hemerobiidae (brown lacewings) Aeolothripidae, Phlaeothripidae Coccinellidae (ladybirds) Carabidae (ground beetles)	nectar pollen plant juice plant juice plant juice pollen nectar, pollen leaves, pollen nectar pollen seeds

How to support natural pest control?

Traditional paradigm: **Enhance diversity** (diversity = stability = services)

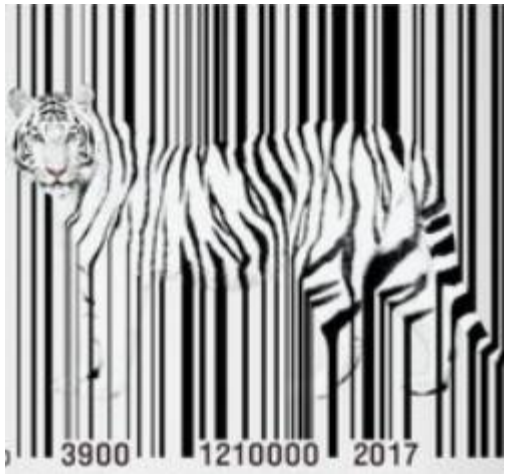
Pimentel, D. (1961) Diversity-Stability hypothesis:
The stability of a community increases with increasing biological diversity

Does it work?

Example biological pest control

How to support natural pest control?

Traditional paradigm: **Enhance diversity** (diversity = stability = services)



Biodiversity is more than just a number !

How to optimize Ecosystem Services?

Focus on groups providing biocontrol / pollination

Different organisms

Different requirements

One size fits all?

Tailor made !

Select plants that optimize biocontrol

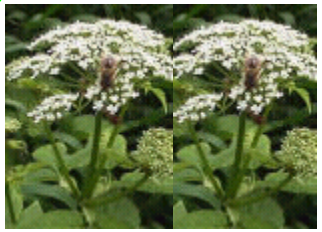
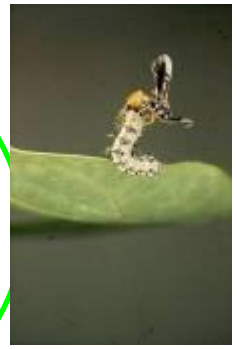
Flower Selection Criteria (Wäckers, 2005)

- Attractivity (Color, odor profile)
- Accessibility of nectar/pollen
- Nutritional composition of nectar/pollen
- Foraging risk

...not all flowers feed natural enemies

Select plants that are attractive and accessible

(Wäckers, 1996, 2004)

	Accessible nectar		Inaccessible nectar	
Attractive	 Aegopodium podagraria	 Vicia sativa		 Leucanthemum vulgare
Non-attractive	 Daucus carota	 Trifolium pratense	 Medicago lupulina	 Trifolium repens
	 Origanum vulgare		 Erigeron annuus	 Achillea millefolium

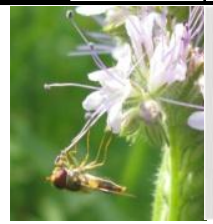
Select to optimize BC benefits

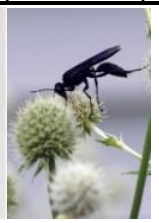
...not all flowers feed natural enemies

Select plants that optimize biological pest control

(Wäckers and van Rijn, 2012)

family		Floral Nectar depth		Longevity (AFLI) Hoverfly *E. balteatus*	Lacewing *C. carnea*	Parasitoids	References parasitoids (species)
Apiaceae		0		+	+	-	Geneau et al., unpubl. (*Microplitis mediator*)
Apiaceae		0		+		+/-	Vattala et al., 2006 (*Microtonus hyperodae*)
Apiaceae		0		+	++	+	Winkler et al., 2009 (*Cotesia glomerata*)
Apiaceae		0		+		+	Winkler et al., 2009 (*Cotesia glomerata*)
Apiaceae		0		+		+/-	Winkler et al., 2009 (*Cotesia glomerata*)
Apiaceae		0		+	++	+/-	Foster & Ruessink, 1984 (*Meteorus rubens*)
Polygonaceae		0		+	+	+	Winkler et al., 2009 (*Cotesia glomerata*)
		0		+	++	-	Nilsson et al., unpubl. (*Trybliographa rapae*)
		0		+		-	Kehrli & Bacher, 2008 (*Minotetrastichus frontalis*)
		1		+	++		
		1		+	+	-	Nilsson et al., unpubl. (*Trybliographa rapae*)
		1		+	+/-	-	Wäckers 2004 (*Cotesia glomerata*)
		1		-	+		
		2		+	+		
		2		+/-	+/-		
		2		+/-	+	-	Wäckers 2004 (*Cotesia glomerata*)
		2		-	+/-		
		3		-		-	Rahat et al., 2005 (*Trissolcus basalis*)
		3		+	++	+/-	Winkler et al., 2009 (*Cotesia glomerata*)
		3		+	+		
		4		-	+/-	+	Rahat et al., 2005 (*Trissolcus basalis*)
		4		-		-	
Boraginaceae		4		+/-	+/-	-	Irvin et al., 2007 (*Gonatocerus* spp.)
Fabaceae		4		-		-	Kehrli & Bacher, 2008 (*Minotetrastichus frontalis*)
Fabaceae		4		+		++	Geneau et al., unpubl. (*Microplitis mediator*)
Fabaceae		4		-	-		



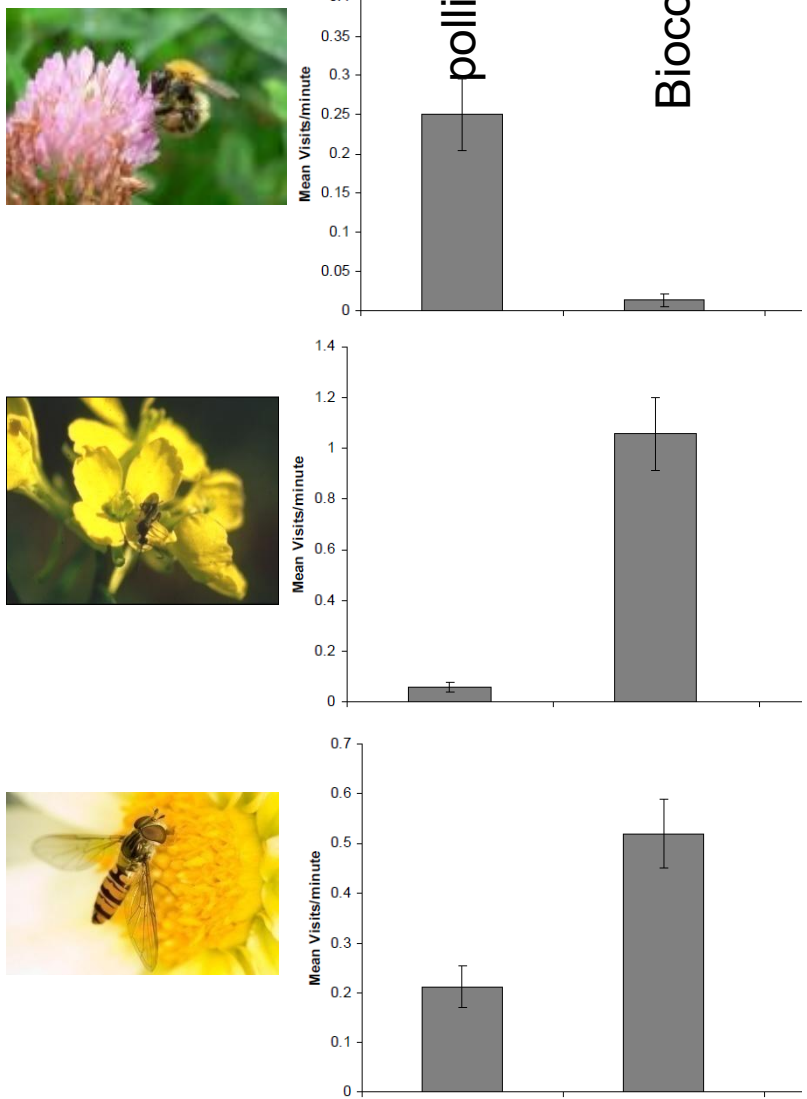


Flower visitation by groups of Service Providers

Pollinators

Predators and parasitoids

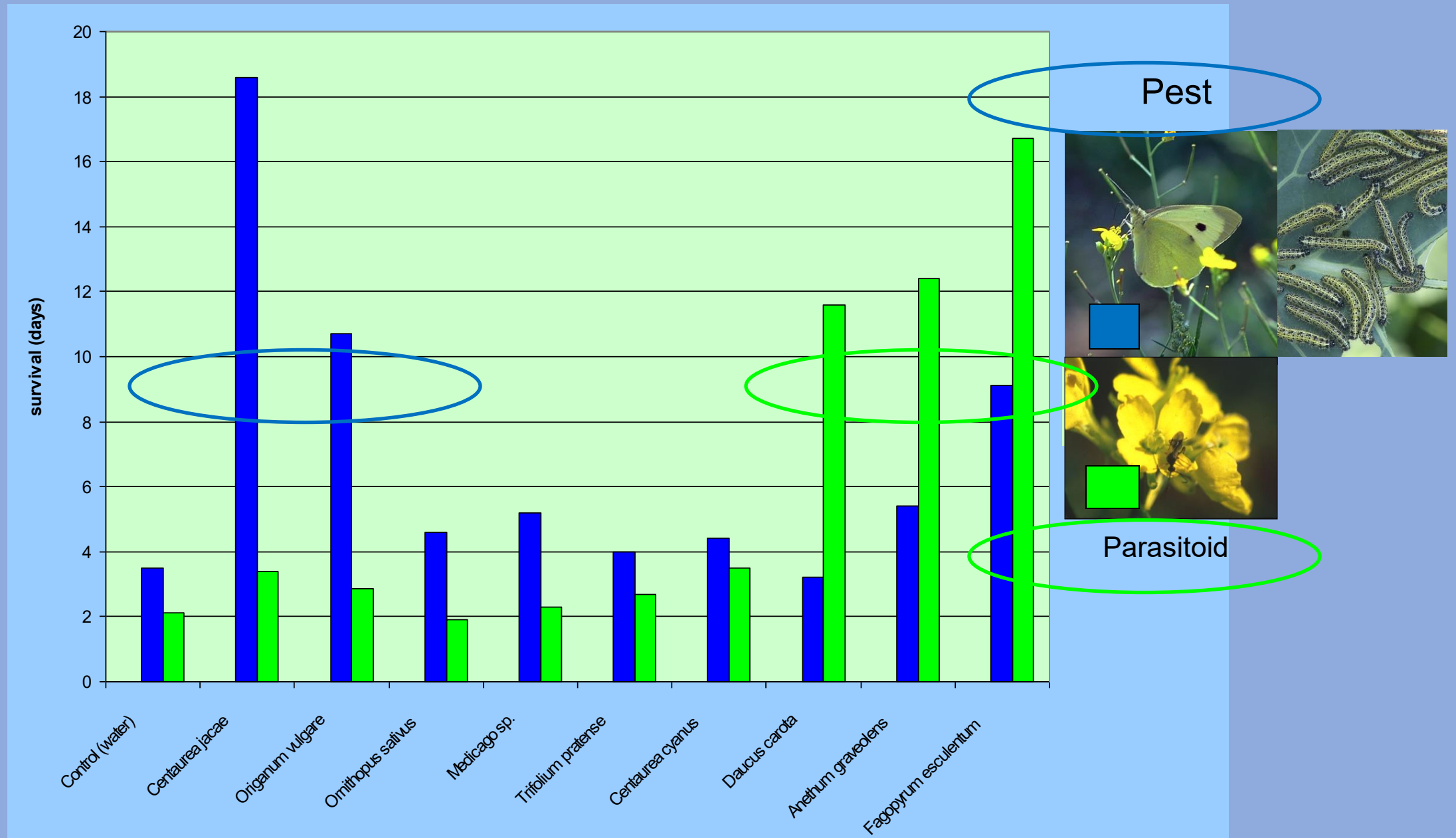
Flower visitation by groups of Service Providers



(Campbell, Biesmeijer Varma & Wäckers, 2012)

Can we select flowers that are not suitable for pests?

(Winkler et al., 2009)



Hedgerows

Nectar
Extrafloral nectar
Pollen
Prey
Shelter
Nesting sites





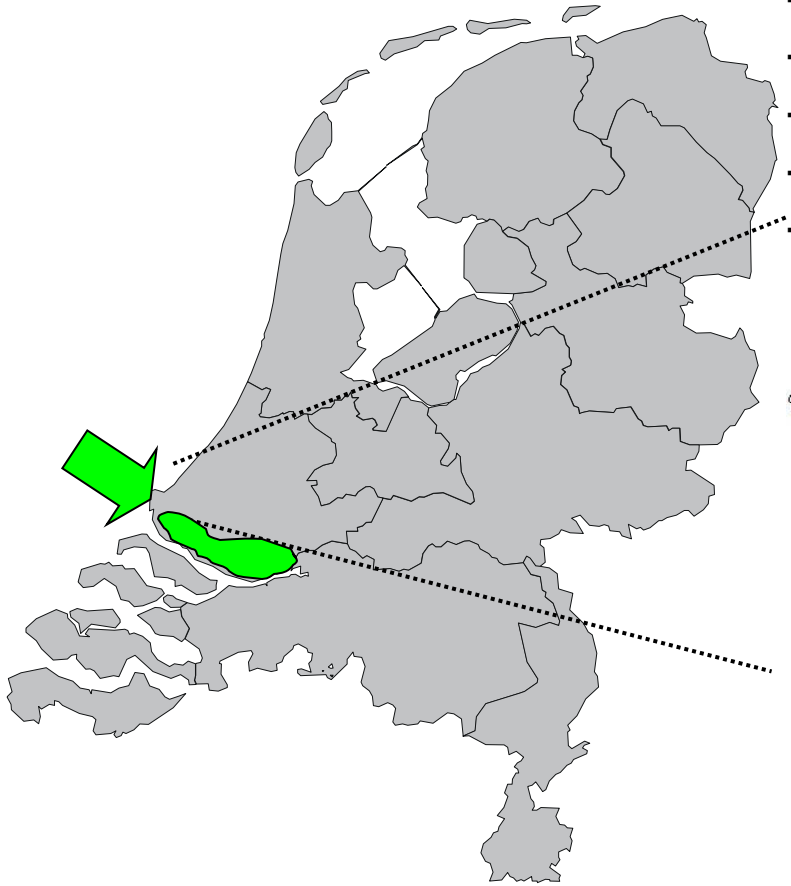

Hedgerow species

Bevordering van nuttige organismen voor plaagbestrijding en bestuiving in open teelten (2022)
Z.A. van Rossum, F.L. Wäckers, A. Janssen & P.C.J. van Rijn. Rapport in opdracht van LNV & Artemis

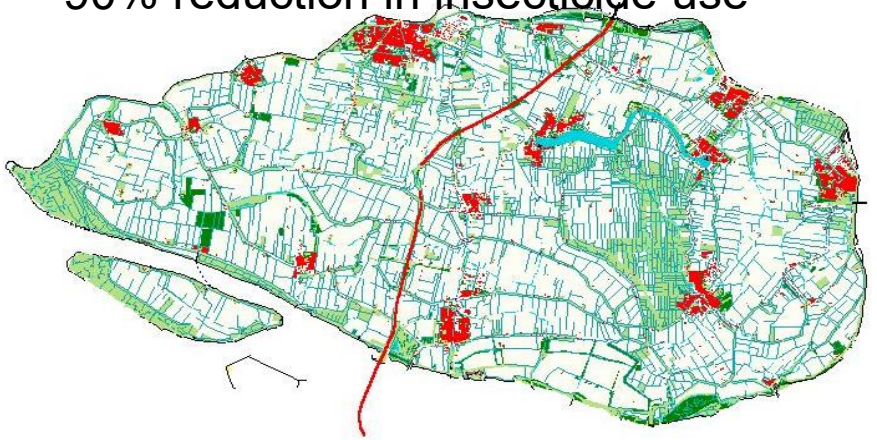
Nederlandse naam	Soortsnaam	Max. hoogte (m)	Extraflorale nectar	Florale nectar bron*	Stuifmeel bron	Bloeiperiode (maand)	Bron van prooien	Periode prooien	Ondersteuning bestrijders	Winterwaard voor plaagsoort**:
Hazelaar	Corylus avellana	6	-	-	+++	1-3	+++	5-7	++	
Zwarte els	Alnus glutinosa	24	-	-	++	1-3	++	6	+	
Gele kornoelje	Cornus mas	6	-	++	+++	3	-			
Grauwe wilg	Salix cinerae	10		+++	++	3-4	++	4-6	+	
Sleedoorn	Prunus spinosa	3	+	++	++	3-4	+++	5-6	++	
Veldesdoorn	Acer campestre	18		+++	+	4	++	4-5	++	
Vogelkers	Prunus padus	15	+	+	+	4	+++	4-5	++	Perzikbladluis[1], vogelkersluis[2]
Schietwilg	Salix alba	20	+	+++	+++	4	+	6	+	zevenbladluis[3]
Gewone Esdoorn	Acer pseudoplatanus	30	-	+++	++	4-5	++		+	
Eenstijlige meidoorn	Crataegus monogyna	4.5	-	+	+	4-5	+++	5-6	++	bacterievuur[4]
Kardinaals-muts	Euonymus europaeus	6	-	+	+	4-5	++	4-6	++	zwarte bonenluis[5]
Gelderse roos	Viburnum opulus	4	+	+	+	5	++	5-6	++	zwarte bonenluis[5]
Rode kornoelje	Cornus sanguinea	3	-	+	+	5	++	5, 9-10	+	
Lijsterbes	Sorbus aucuparia	9		+	+	5	++		++	
Vuilboom	Frangula alnus	3	-	++	++	5	-			vuilboomluis[6]
Wilde liguster	Ligustrum vulgare	3	-	+	+	5-6	-			
Hondsroos	Rosa canina	3	+	-	+++	5-6	++	5-6	+	roos-grasluis[2], aardappeltopluis[6]
Gewone vlier	Sambucus nigra	7	+	+	+	5-6	++	6	+	
Linde	Tilia sp.	35		+++	+++	6-7	+++	5-6	++	

Taking it to the Farmer

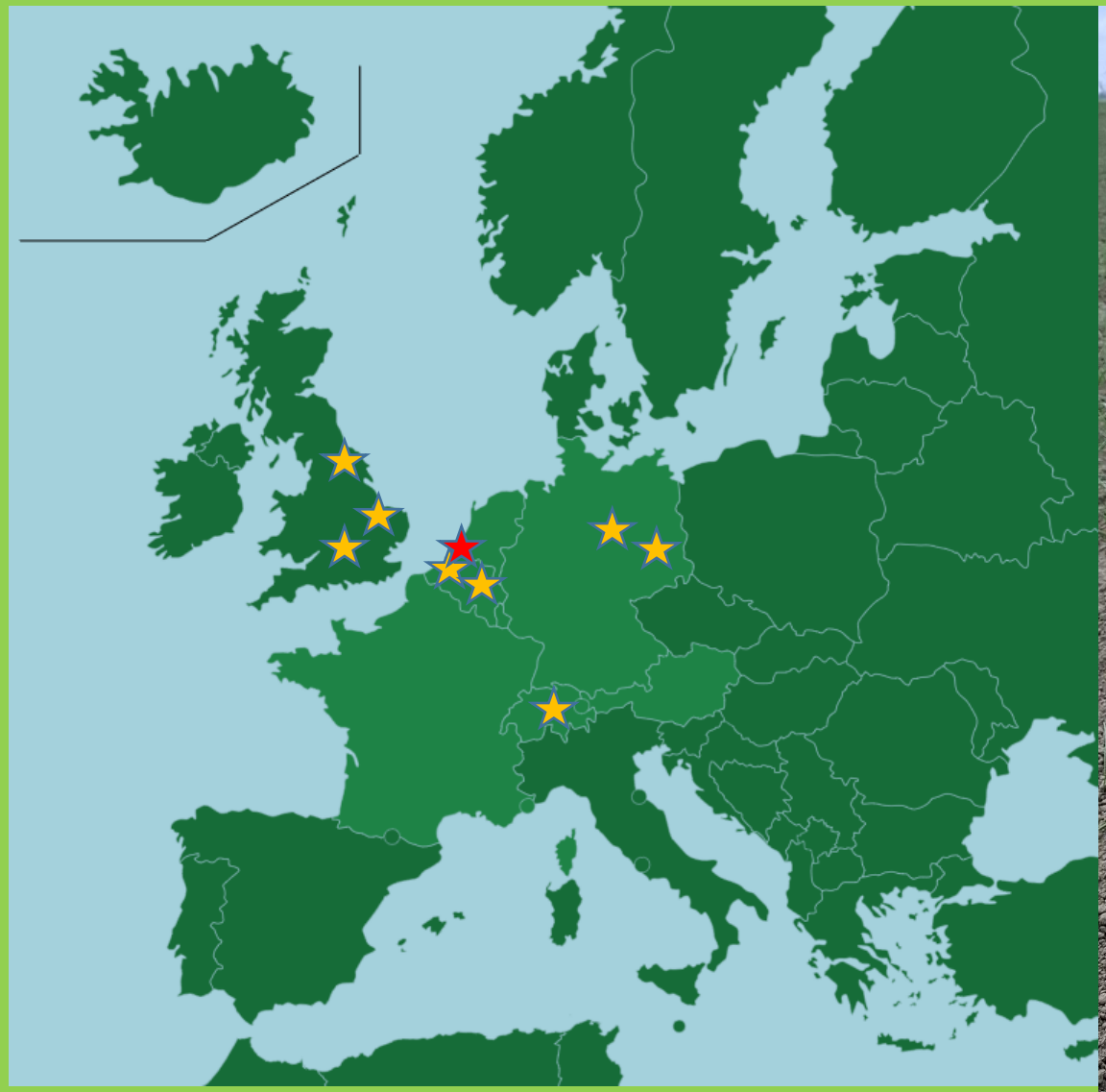
FAB (Functional Agrobiodiversity)



- > 20 years running
- Organized by Farmers (cooperative)
- 50% of farmers participate
- > 800 km of targeted flower margins
- 90% reduction in insecticide use

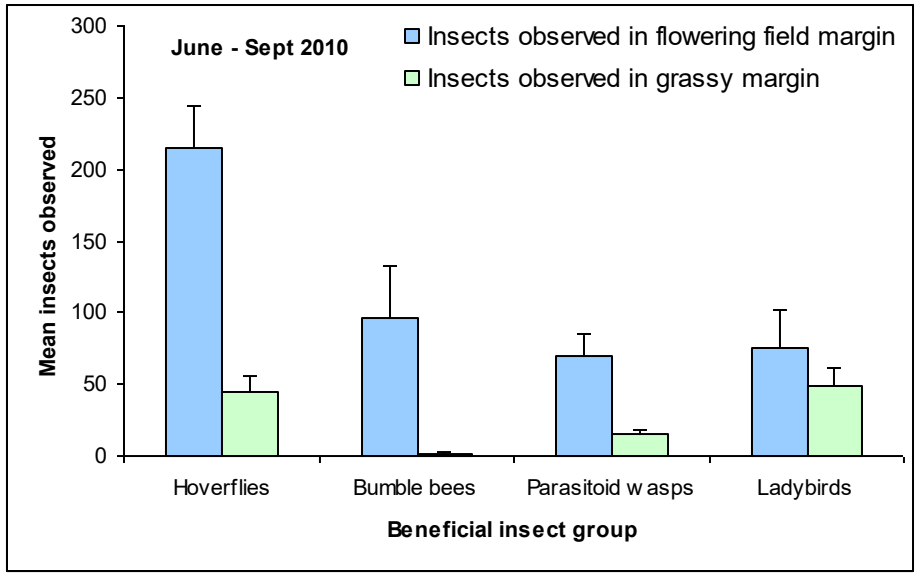


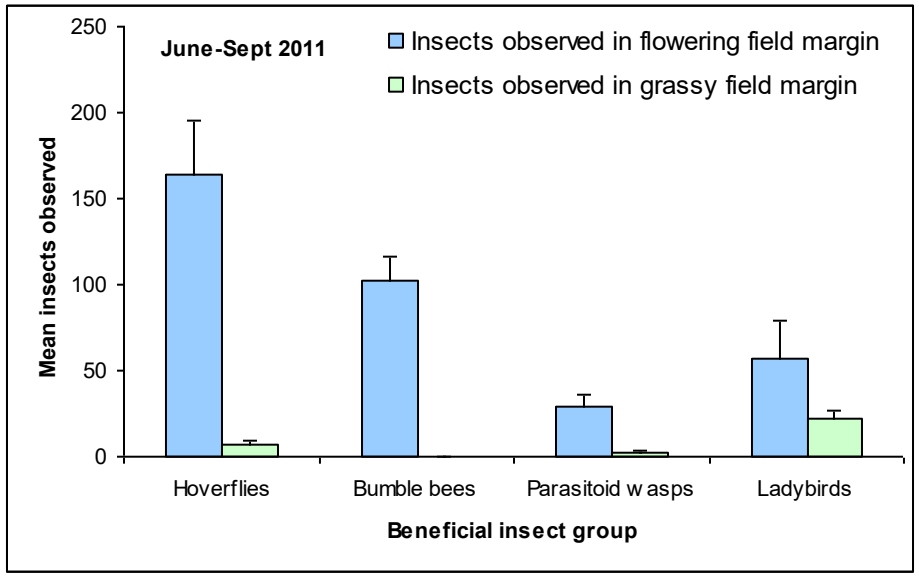
European large scale functional agrobiodiversity projects (Since 2004)



Where’s the evidence?

Beneficial insects in field margins





Evidence for feeding?

(Steppuhn and Wackers, 2004)

Do diverse bird conservation margins benefit biological pest control?

Meteorus autographae

Parasitoid feeding at a vetch nectary

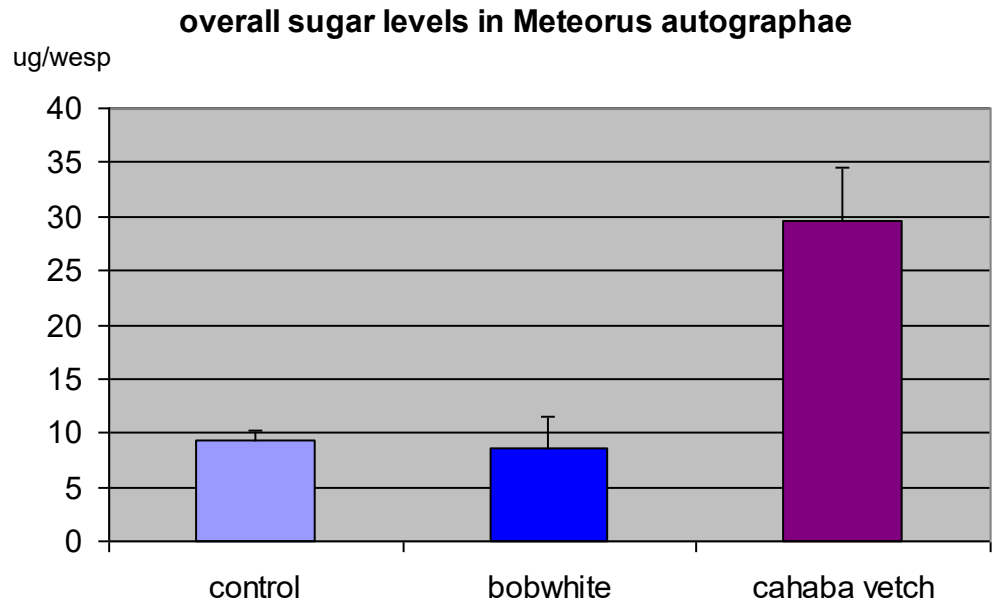
Conclusions

High diversity field margins for bobwhite quail conservation failed to provide food to a biological control agent and did not enhance biological pest control in the adjacent crop.

Parasitoids did clearly benefit from pure stands of cahaba white vetch.

Impact on Biocontrol is a function of **resource availability (*flower suitability),*** rather than diversity.

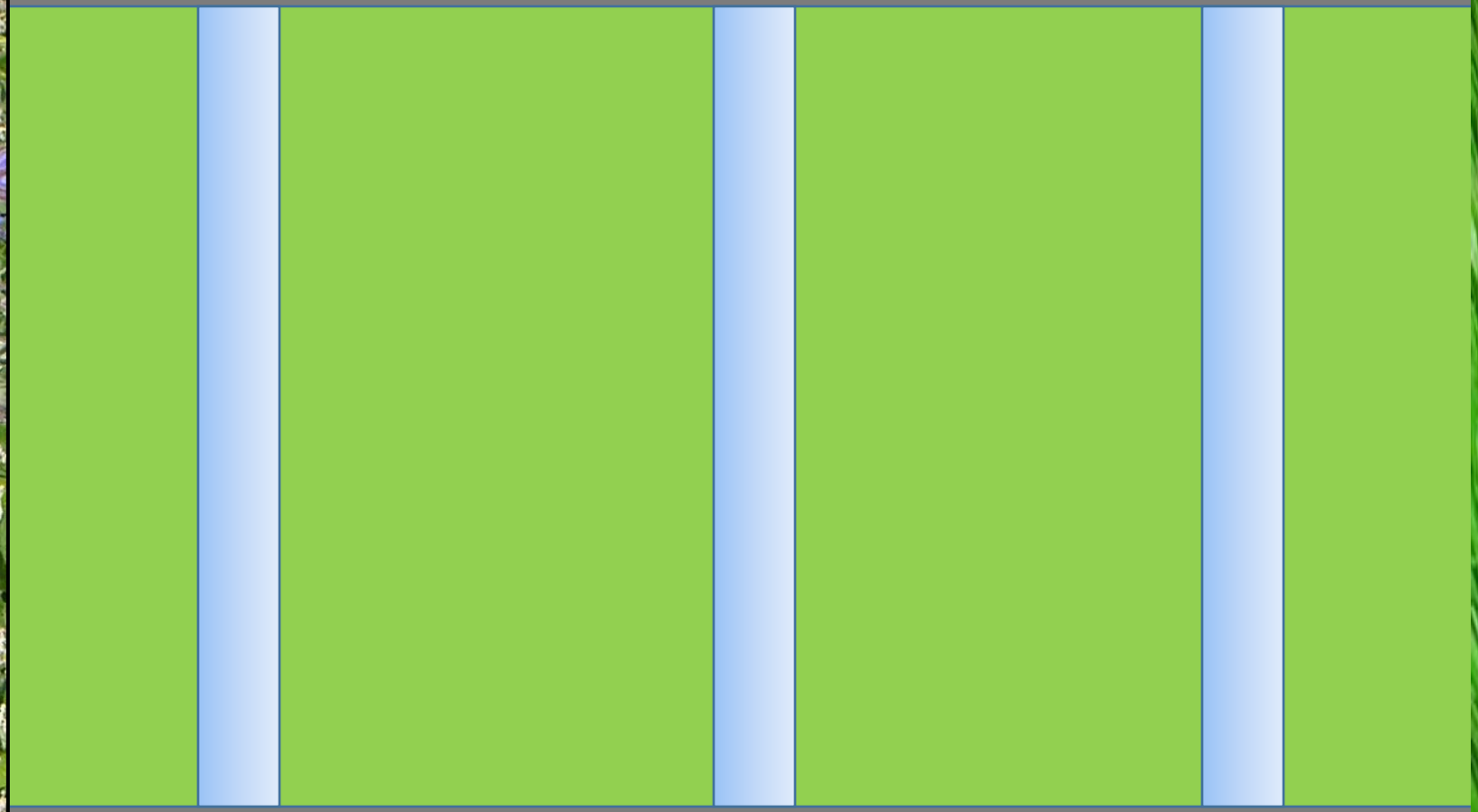
(Olson and Wackers, 2006)



Parasitoid feeding at a vetch nectary

Evidence for spillover into the crop / pest control ?

Crop sampling

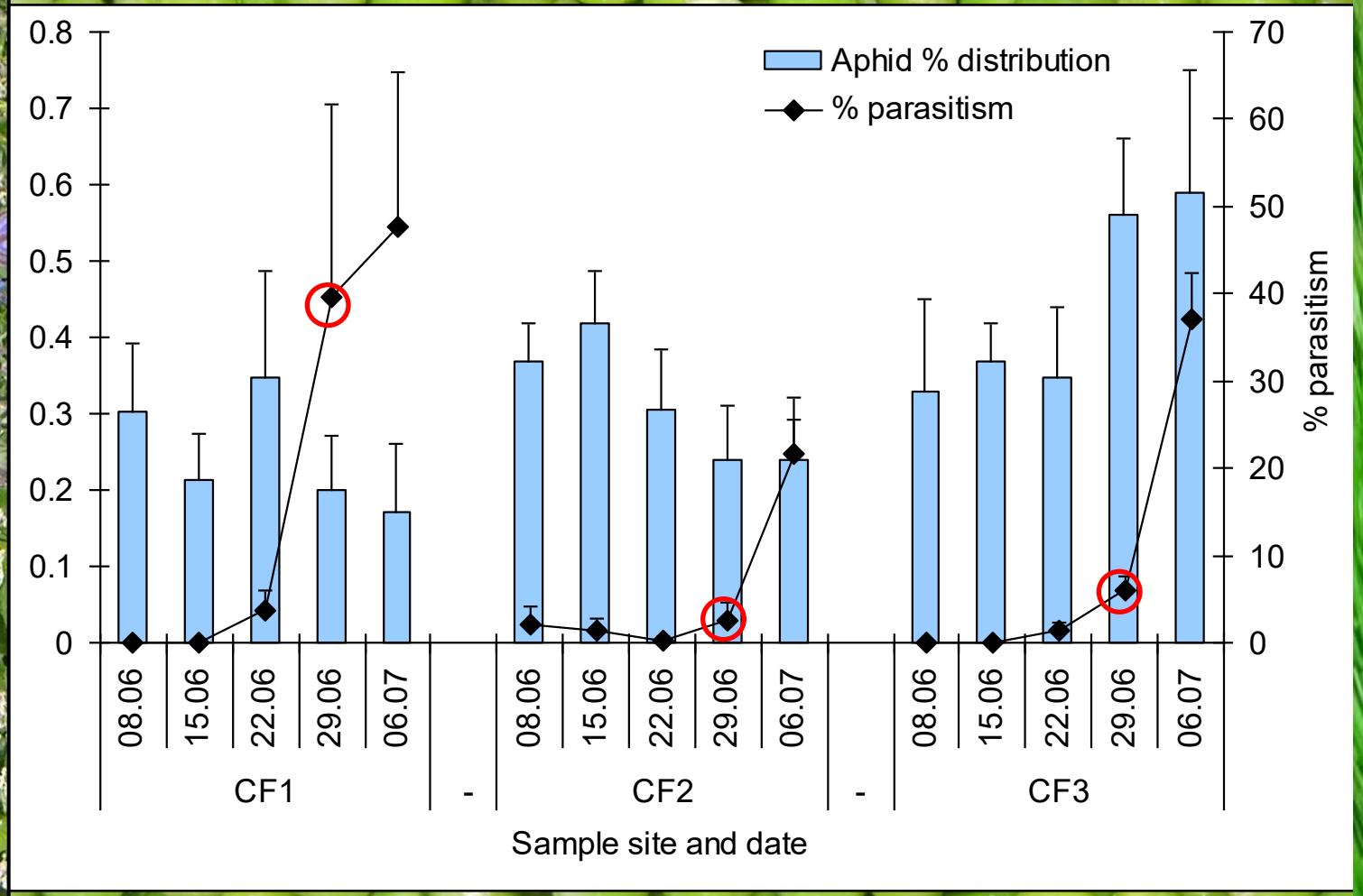


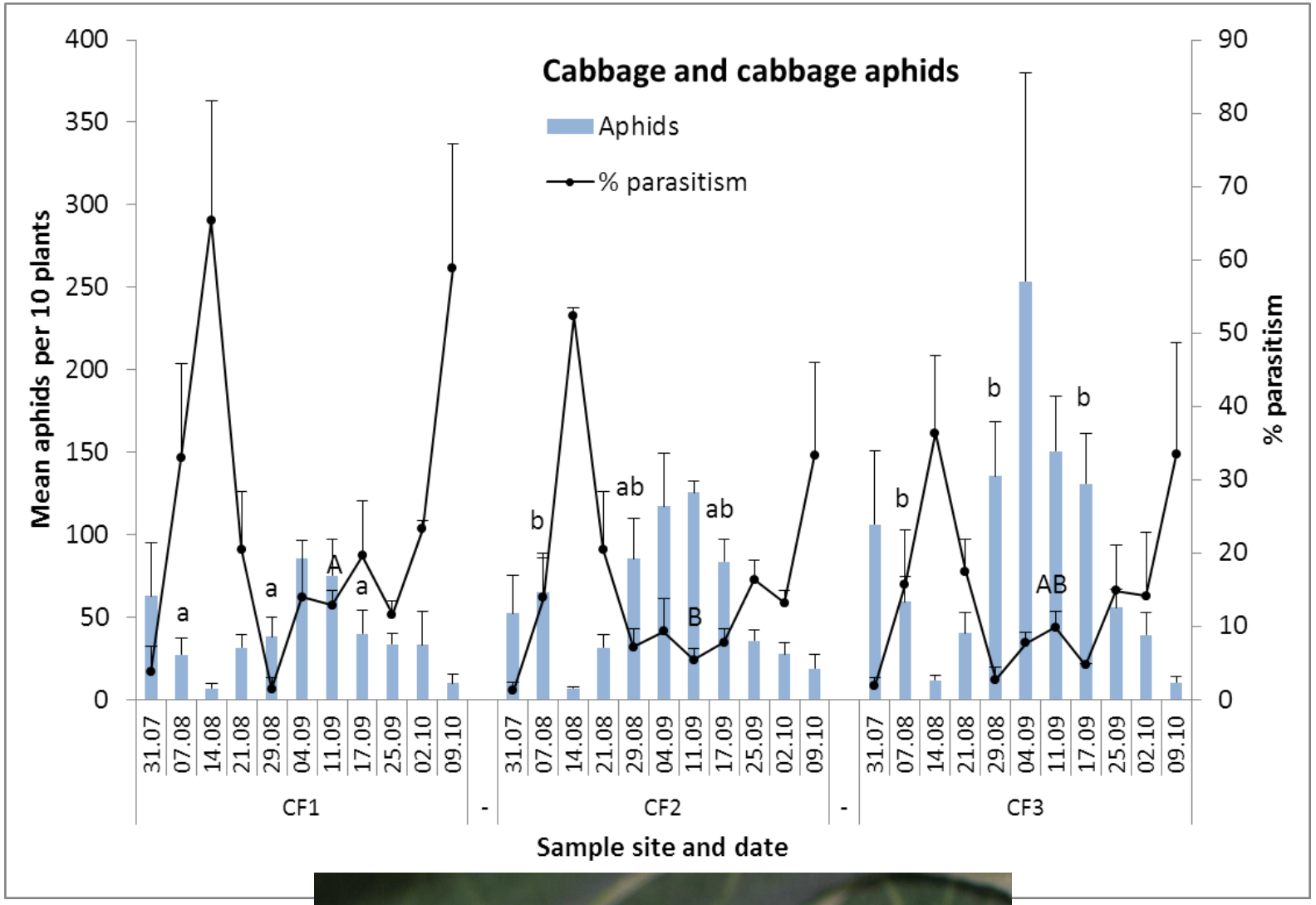
CF1
10m flower

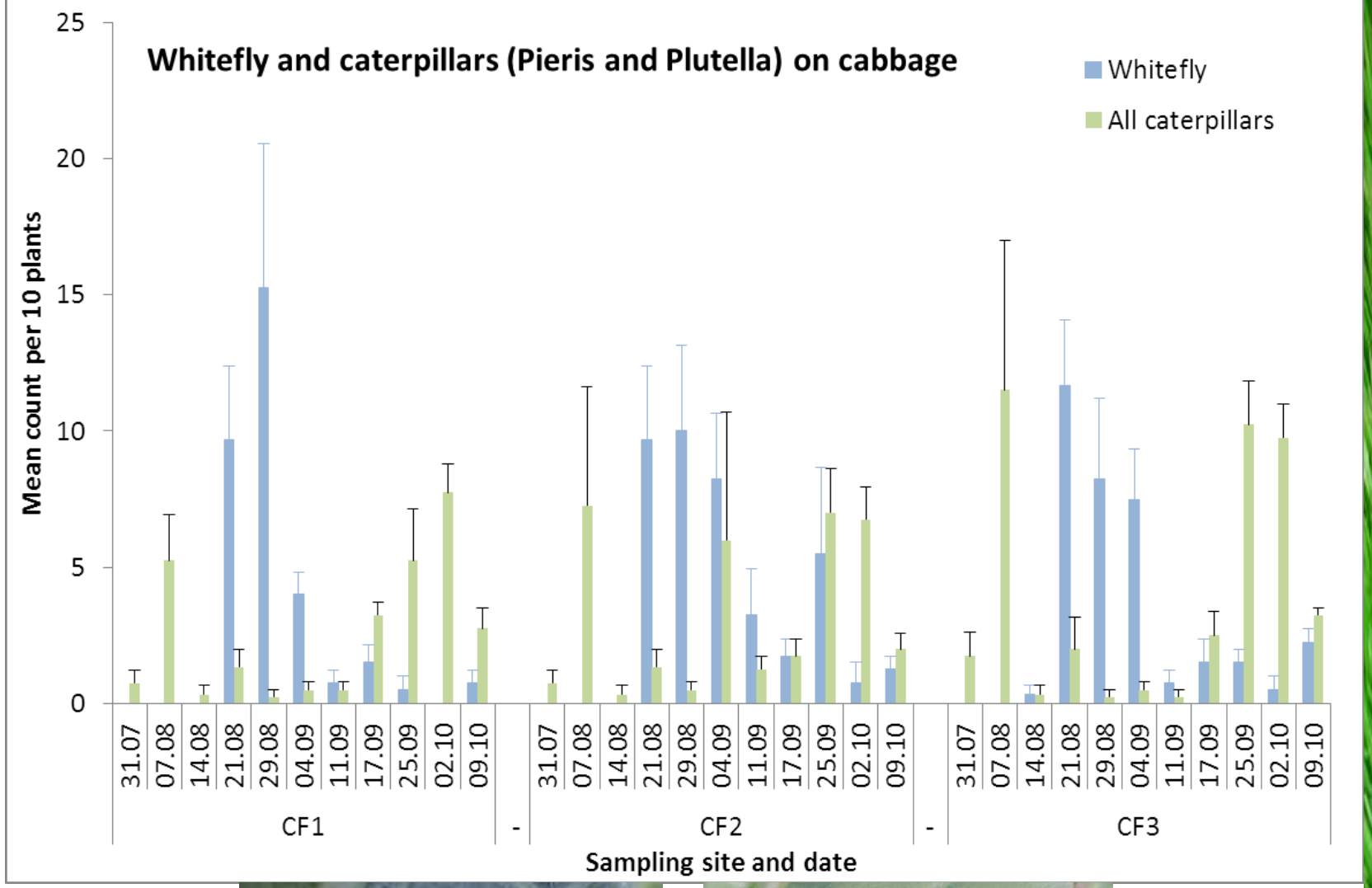
CF2
50 m

CF3
10m grass

Aphids in peas

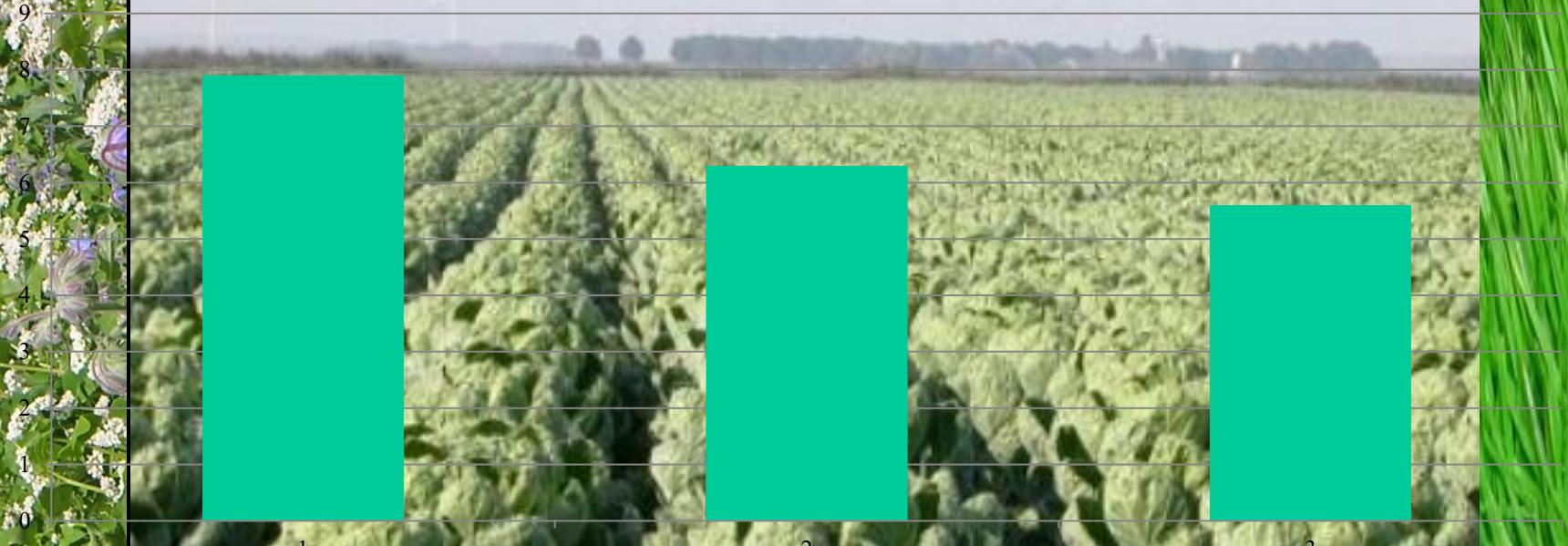



Cabbage and cabbage aphids
Aphids
% parasitism
Mean aphids per 10 plants
% parasitism
Sample site and date
CF1
CF2
CF3
31.07
07.08
14.08
21.08
29.08
04.09
11.09
17.09
25.09
02.10
09.10
a
a
A
a
b
ab
B
ab
b
b
AB
b


Whitefly and caterpillars (Pieris and Plutella) on cabbage
Whitefly
All caterpillars
Mean count per 10 plants
25
20
15
10
5
0
31.07
07.08
14.08
21.08
29.08
04.09
11.09
17.09
25.09
02.10
09.10
CF1
CF2
CF3
Sampling site and date

Impact on yield?

Brassica
(yield in tonnes/ha)

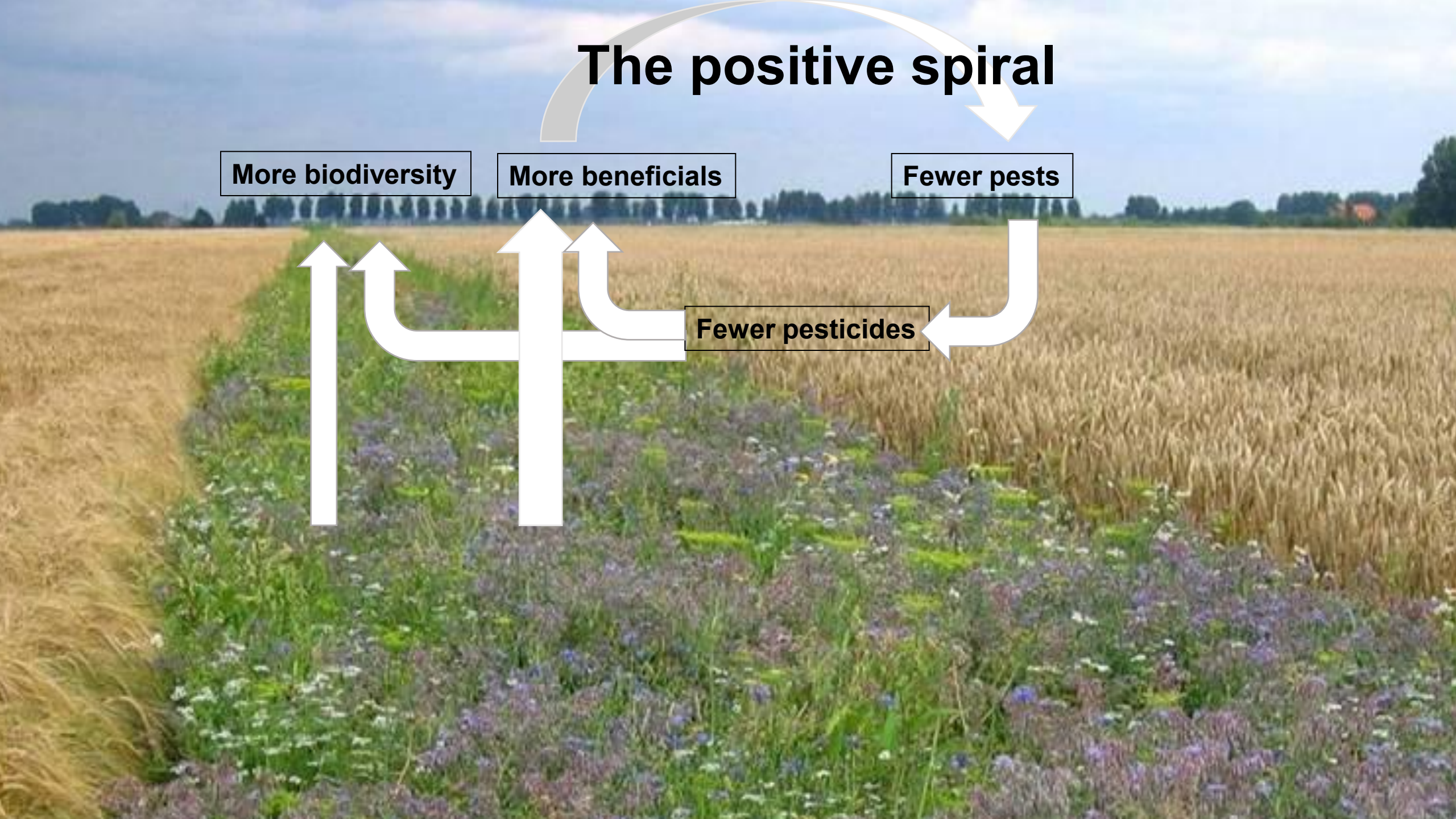


peas (yield in tonnes/ha)

Conclusions Evidence

Targeted biocontrol flower margins

- Increase number of beneficials in the margin
- Increase energy reserves (proof of feeding)
- Beneficials move over into the crop
- Crop pests are effectively controlled
- Crop yield can be improved


The positive spiral
More biodiversity
More beneficials
Fewer pests
Fewer pesticides

Environment and productive Farming
are NOT conflicting objectives

They go hand in hand

Annual vs Perennial ?

Annual flower strips

Advantages:
- Flexibility
- Can be adjusted to particular crop

Disadvantages:
- No overwintering resources for beneficials
- Annual cost of seeds
- More labour (planting)
- More problems with annual weeds

Perennial flower strips

Nadelen:
- Minder flexibel
- potentieel probleem met vergrassing

Advantages:
- Provides food + overwintering sites
- Earlier flowering
- Sowing only once in five years
- Better suppression of annual weeds

Disadvantages:
- Less flexible
- Potential problems with grasses
- Potential problems with perennial weeds

Food supplementation

- Pollen
- Sugars
- Factitious Prey
    - Ephestia kuehniella
    - Artemia spp
    - Prey mites
- Artificial diets

Paradigm shift:

Allows establishment of biocontrol before the pest arrives!

Typha pollen as food supplement

Pollen as food supplement in onion crops

Food supplements to support natural pest control?

Example Onions

Conventional
4 insecticide treatments

Onion Thrips
(*Thrips tabaci*)

No insecticides
2 pollen applications


biobest
SUSTAINABLE CROP MANAGEMENT

<u>Yield:</u>

Diameter + 8%

Weight +15%

Spraying Food Supplements: Sugars?

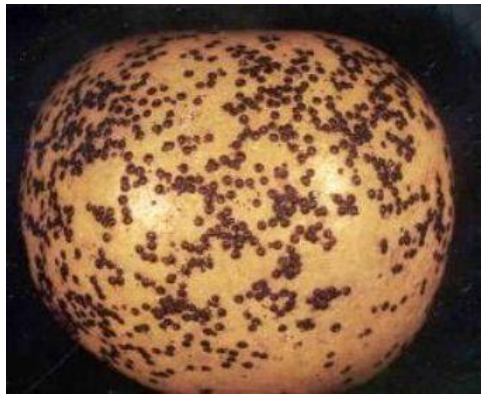
Inspired by Nature:

Extrafloral nectaries

sugar sprays in citrus to support *Aphytis melinus?*

Tena et al., 2015

- California red scale is most important pest in citrus
- *Aphytis melinus* is thought to be the key parasitoid
- Natural populations provide insufficient control
- Parasitoid releases?
- Sugar supplements?



ivia
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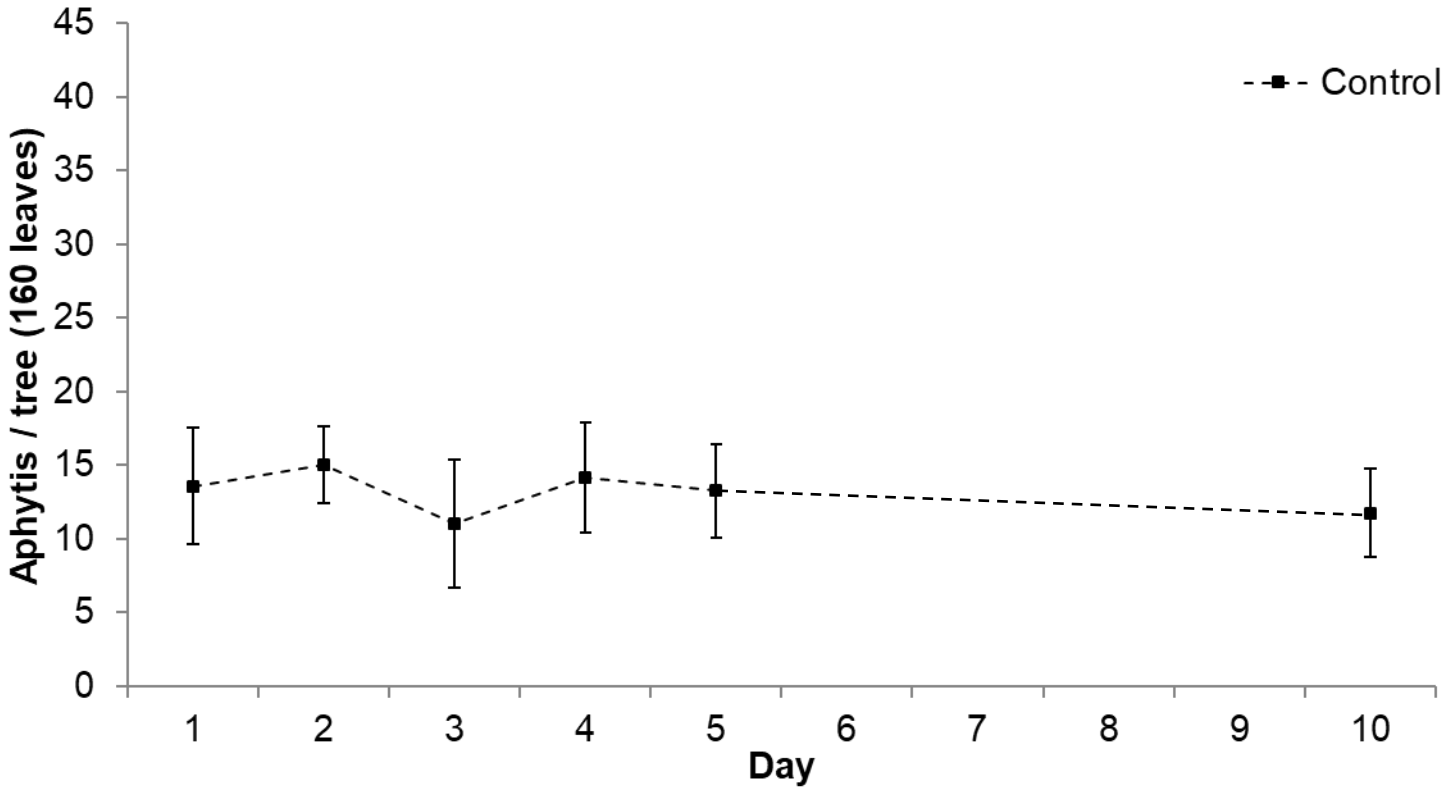
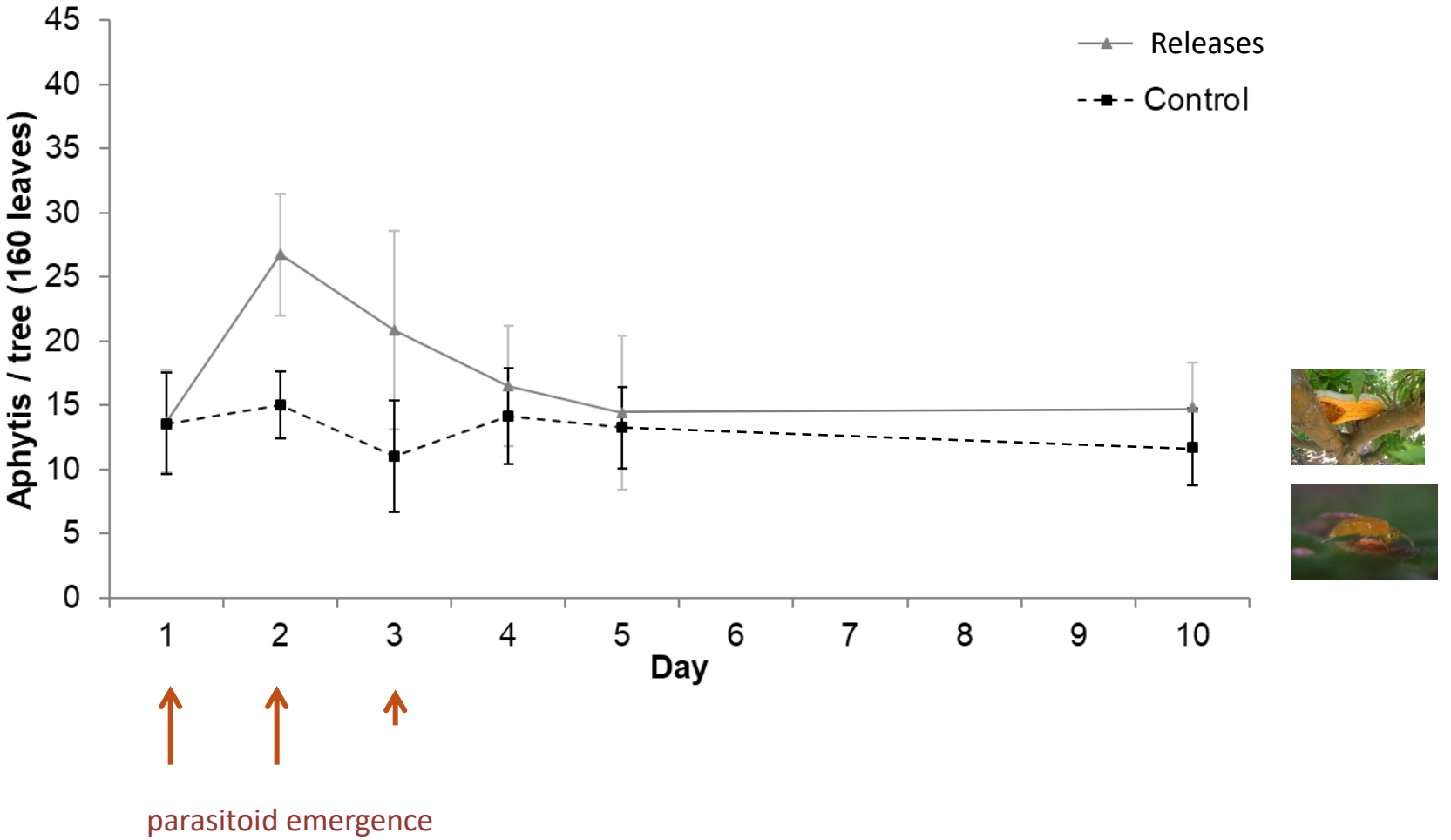
de investigaciones agrarias

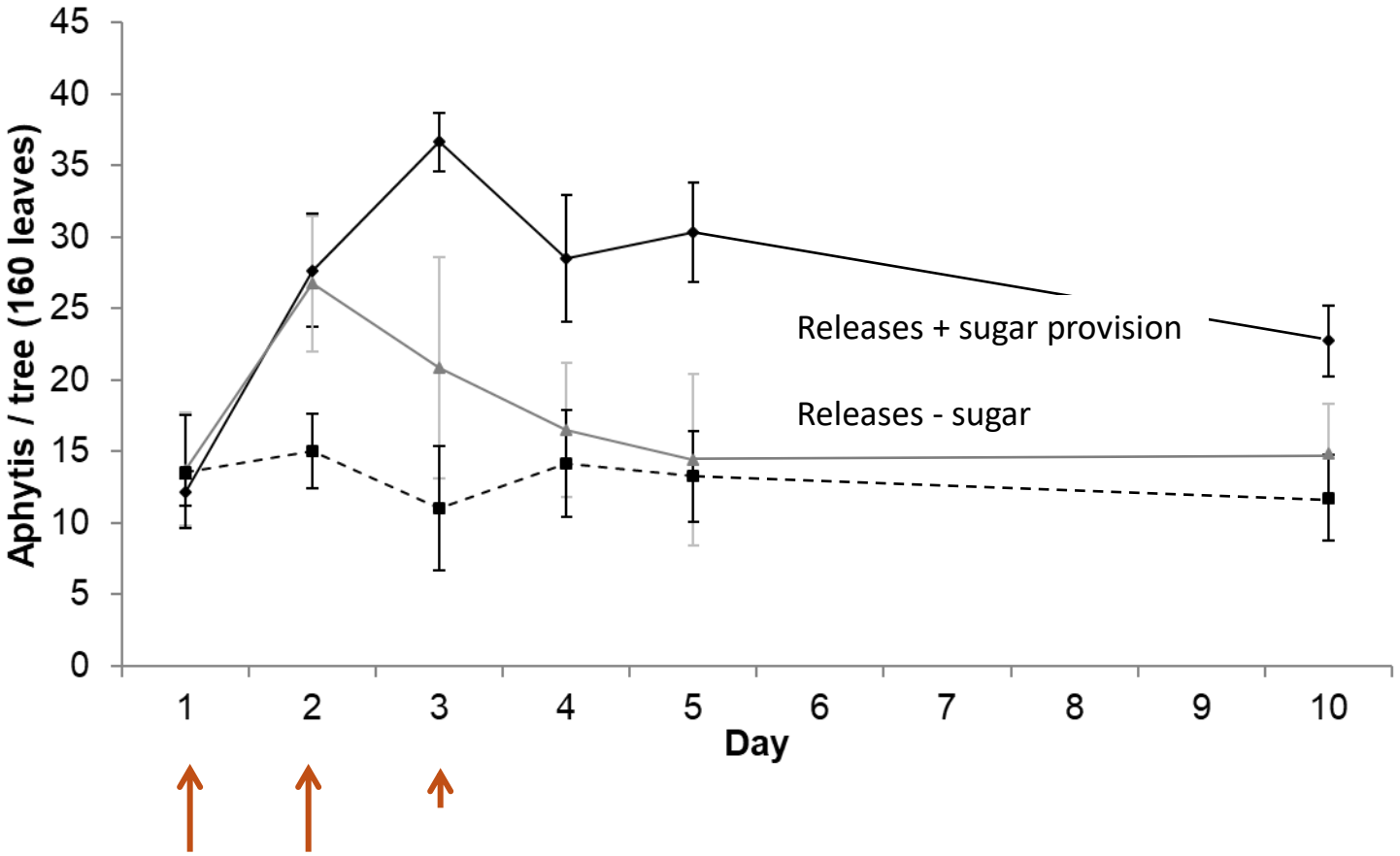
Do releases increase parasitoid density?



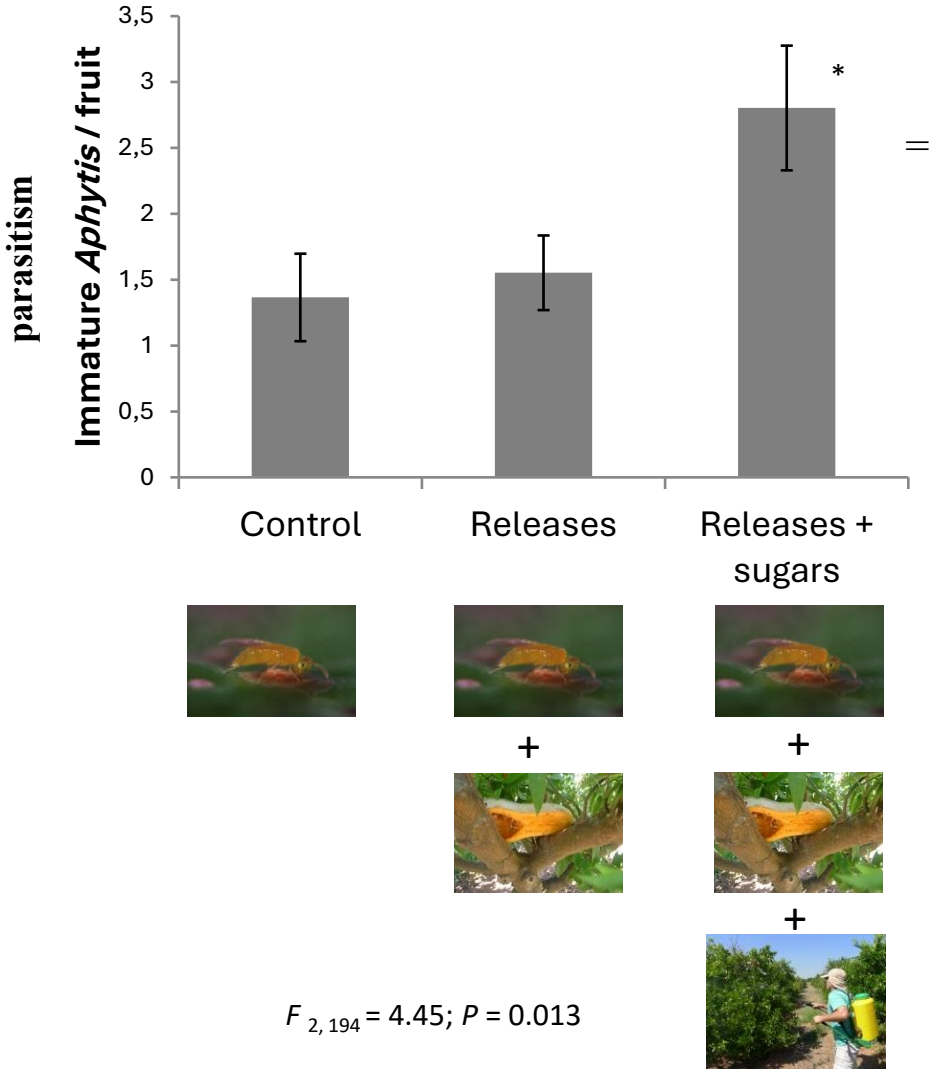
Do releases increase parasitoid density?



Do releases ***+ sugar*** increase parasitoid density?



Do sugars increase parasitism?



= 30% parasitism

$F_{2, 194} = 4.45$; $P = 0.013$

Thank You

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ANTS

Honeydew:

A problem food

Alternative: Ant Distraction

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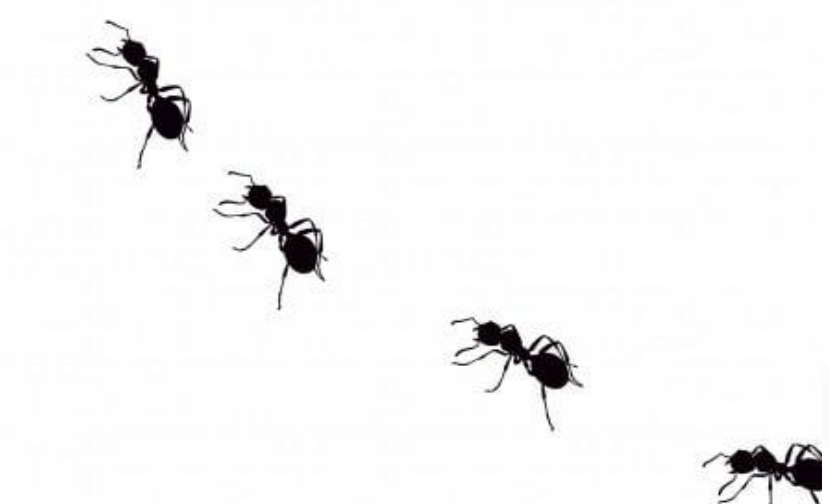
Attract and distract: Manipulation of a food-mediated protective mutualism enhances natural pest control

Felix L. Wäckers[a], Jesús Sánchez Alberola[b], Ferran Garcia-Marí[b], Apostolos Pekas[a,*]

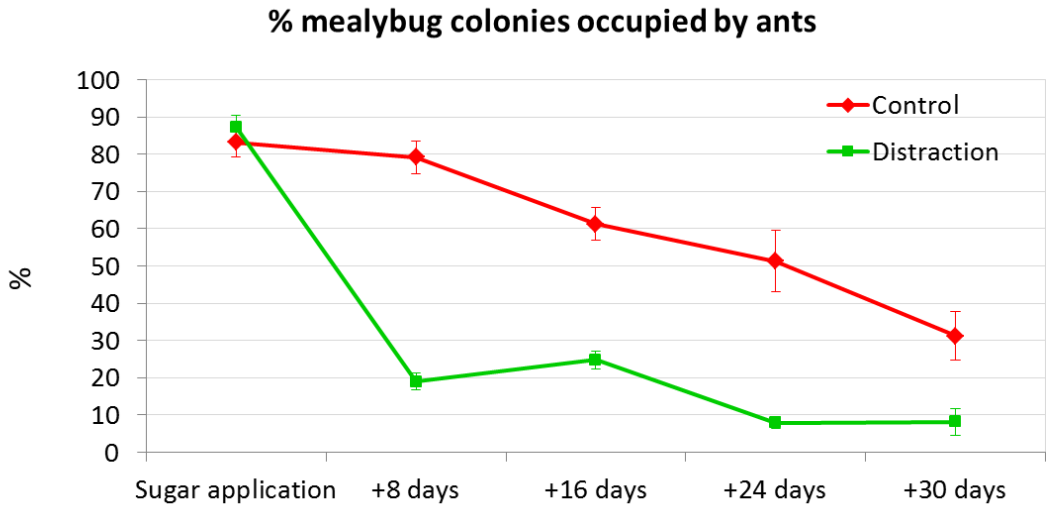
Ant Distraction

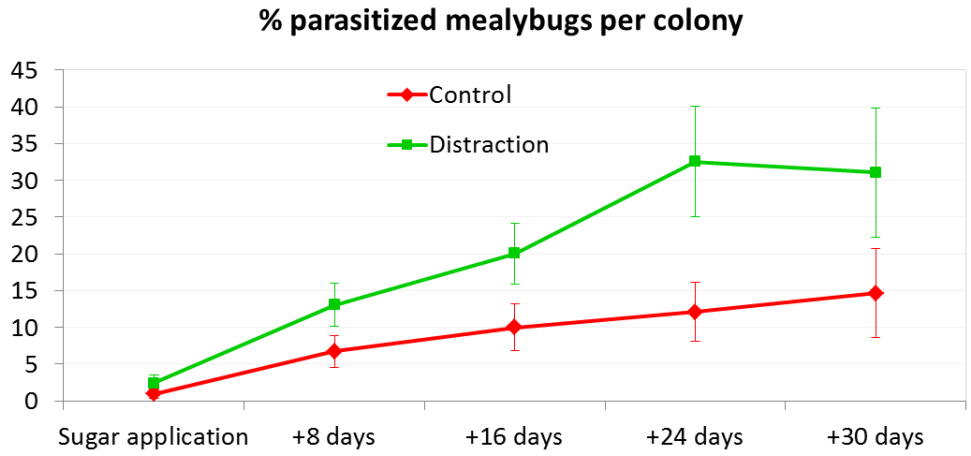
Photo Dirk Sanders



Ant Distraction

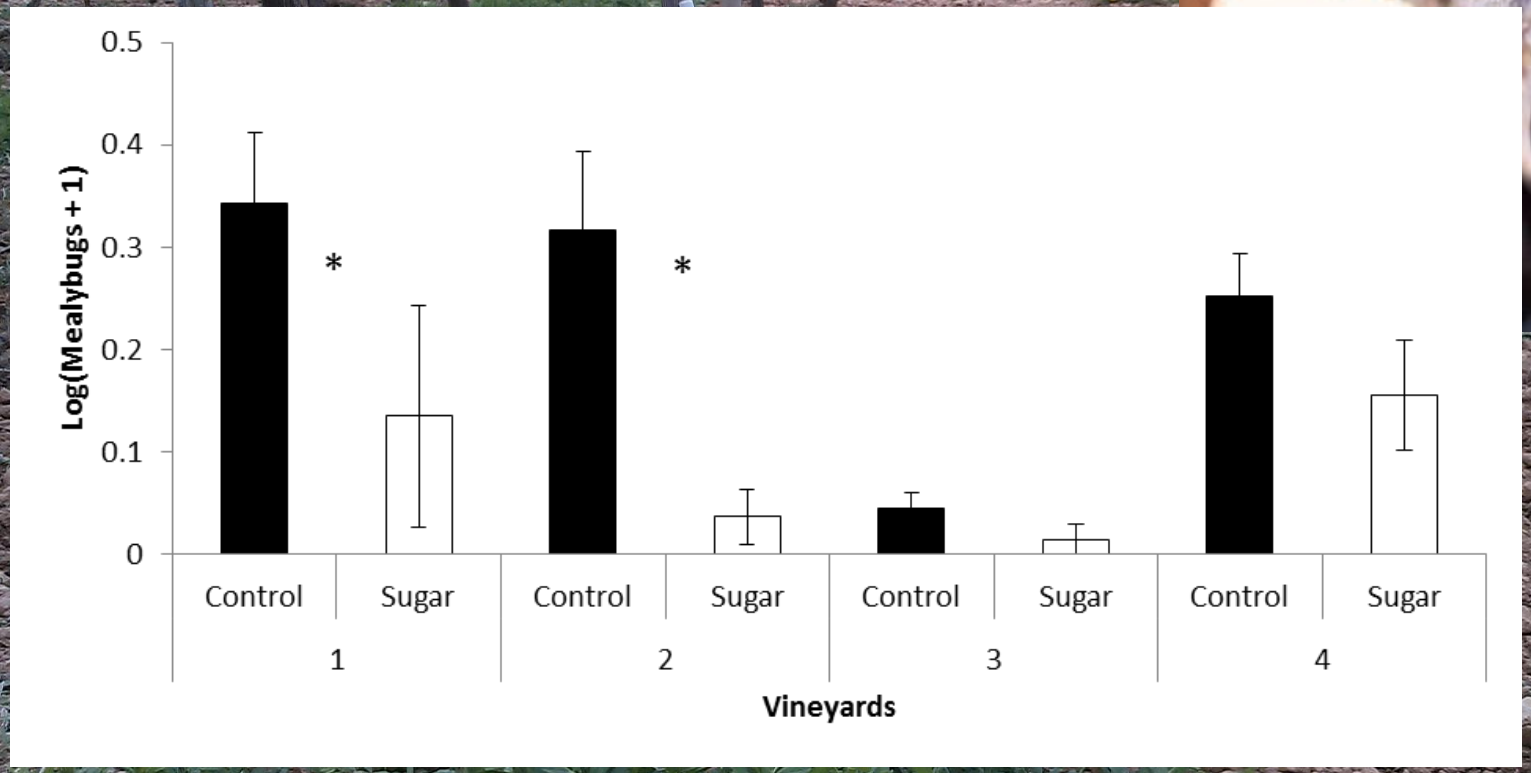
Citrus Trials 2015





Enhanced natural parasitism by *Anagyrus pseudococci*

Ant distraction in vineyards (mealybugs)



Rosy Apple Aphid (since 2021, the Netherlands)

Rosy Apple Aphid (2021, the Netherlands)