Innovation in crop protection: challenges and opportunities

Prof Toby Bruce,
Keele University

Keele University

“High yielding varieties”







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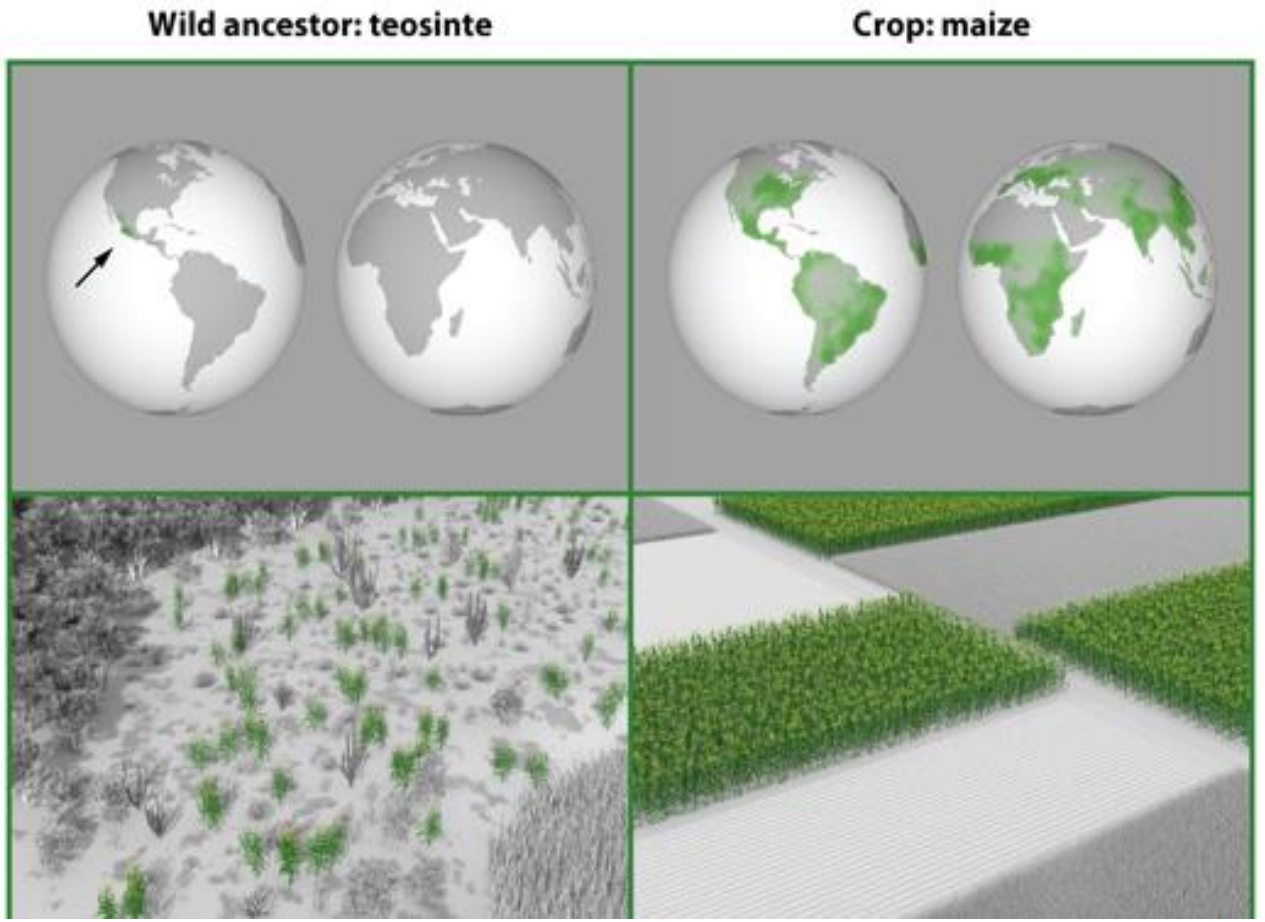
University

Agricultural ecosystems are unnatural, human managed environments



Region

Climate
Elevation
Time since crop introduction
Biogeographical history

Landscape

Frequency of disturbance
Habitat diversity

Chen *et al.* (2015) Annu. Rev. Entomol. 60: 35- 58

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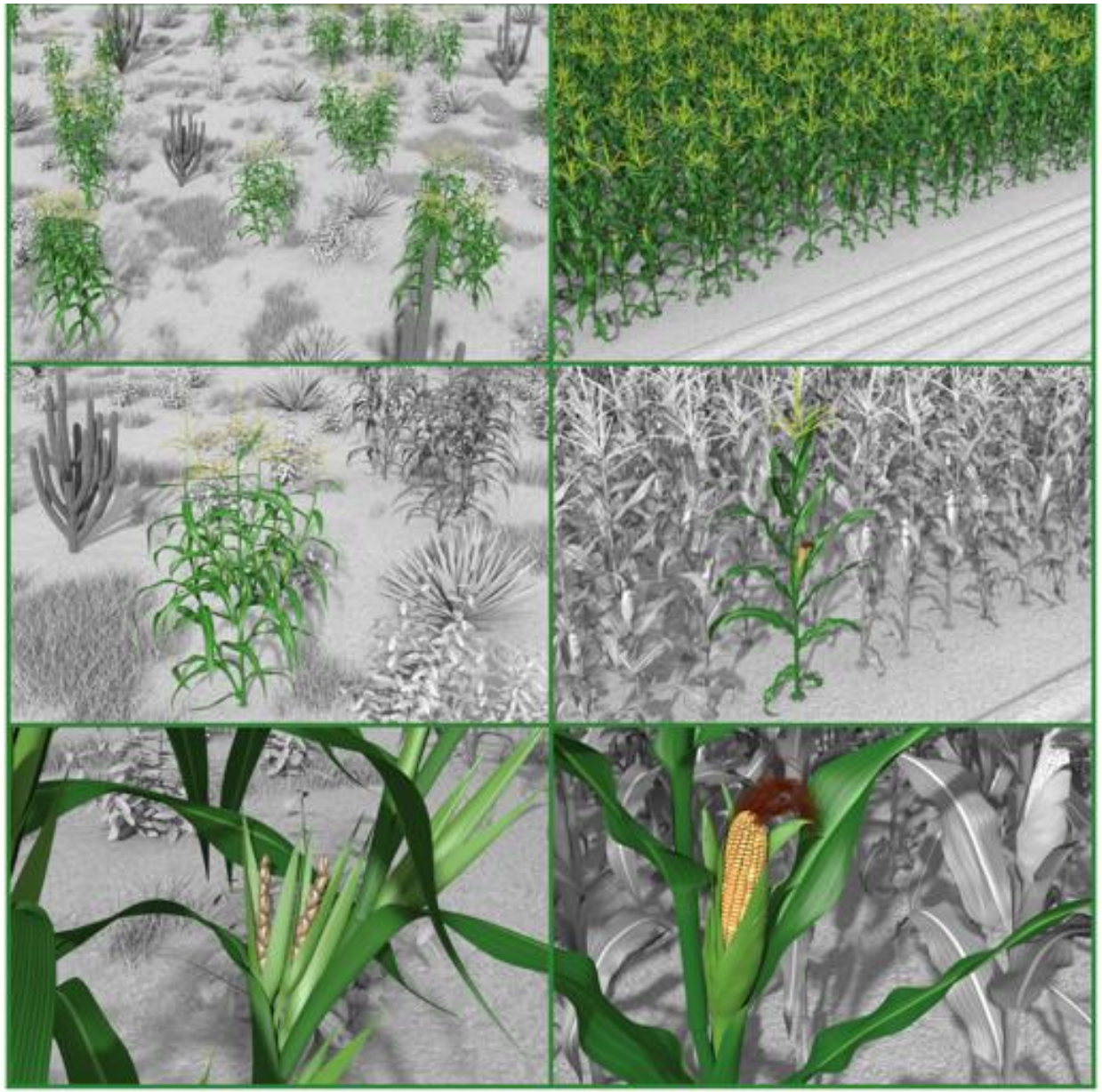
Agricultural ecosystems are unnatural, human managed environments



Habitat or field

Plant species diversity
Plant species density
Soil community and nutrients
Plant genetic diversity
Frequency of disturbance
Tillage
Apparency

Individual plant

Plant architecture
Branching
Plant phenology
Chemical defense
Infochemical induction
Nutrient composition

Plant trait

Gigantism
Trichomes
Tissue toughness
Morphology
Shattering

Chen *et al.* (2015) Annu. Rev. Entomol. 60: 35- 58

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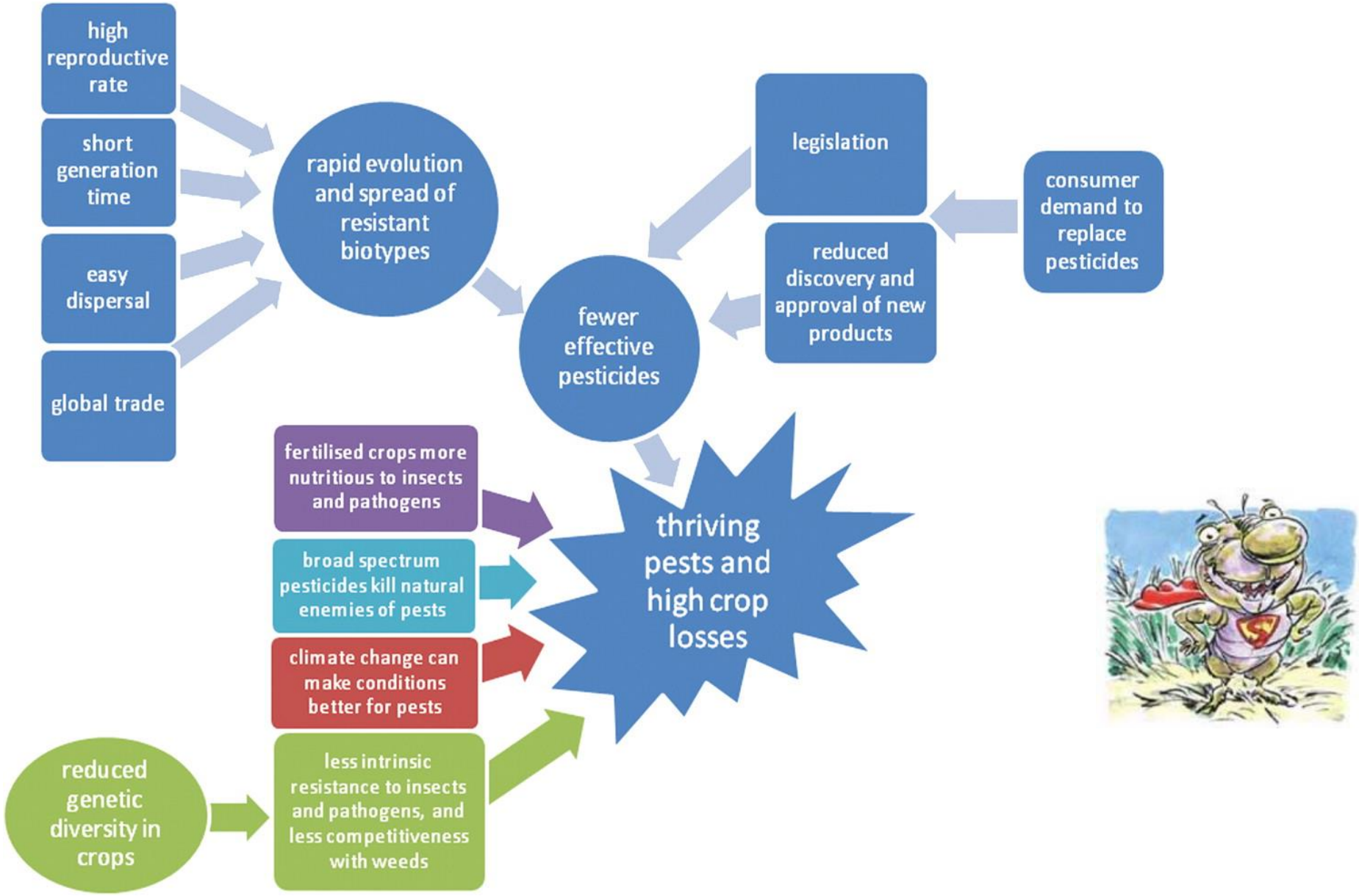
Agricultural environments are simplified and are vulnerable to pests

Lush monocultures of artificially selected high yielding varieties grown with fertiliser

Factors influencing crop protection in an agro-ecosystem



Bruce (2012) J. Exp. Bot. 63: 537-541

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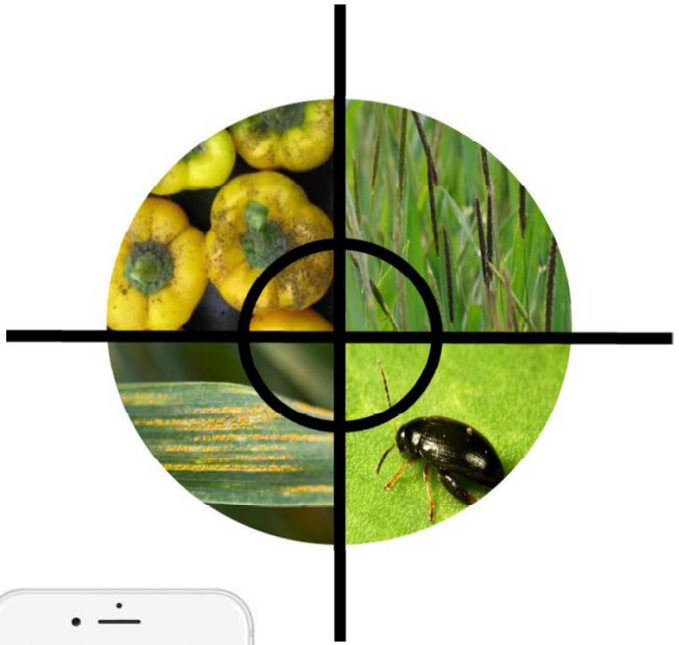


TARGET	NUMBER OF TIMES REPORTED
Black grass	166
Grey field slug	114
Cereal aphids	102
Cabbage Stem Flea Beetle	95
Yellow Rust of Wheat	83
Septoria leaf blotch	75
Cleavers	67
Light Leaf Spot	66
Bromes	63
Wild Oat	59
Peach-potato aphid	56
Phoma stem canker of oilseed rape	51
Sclerotinia stem rot of oilseed rape	50
Fusarium ear blight	50
Pollen beetle	48
Bruchid beetle	47
Charlock	46
Chocolate spot	46
Potato cyst nematode	43
Pea and bean weevil	42
Orange wheat blossom midge	42
Mayweed	42
Chickweed	42
Italian rye-grass	39
Early Blight	37
Leatherjackets	36
Brown Rust	35
Poppy	33
Net Blotch	28
Late blight	25
Wheat Bulb Fly	19
Groundsel	12
Diamondback moth	8

Bruce (2016) Food and Energy Security 80: 89-96

Daniel White @dpw674 · 16 Sep 2014

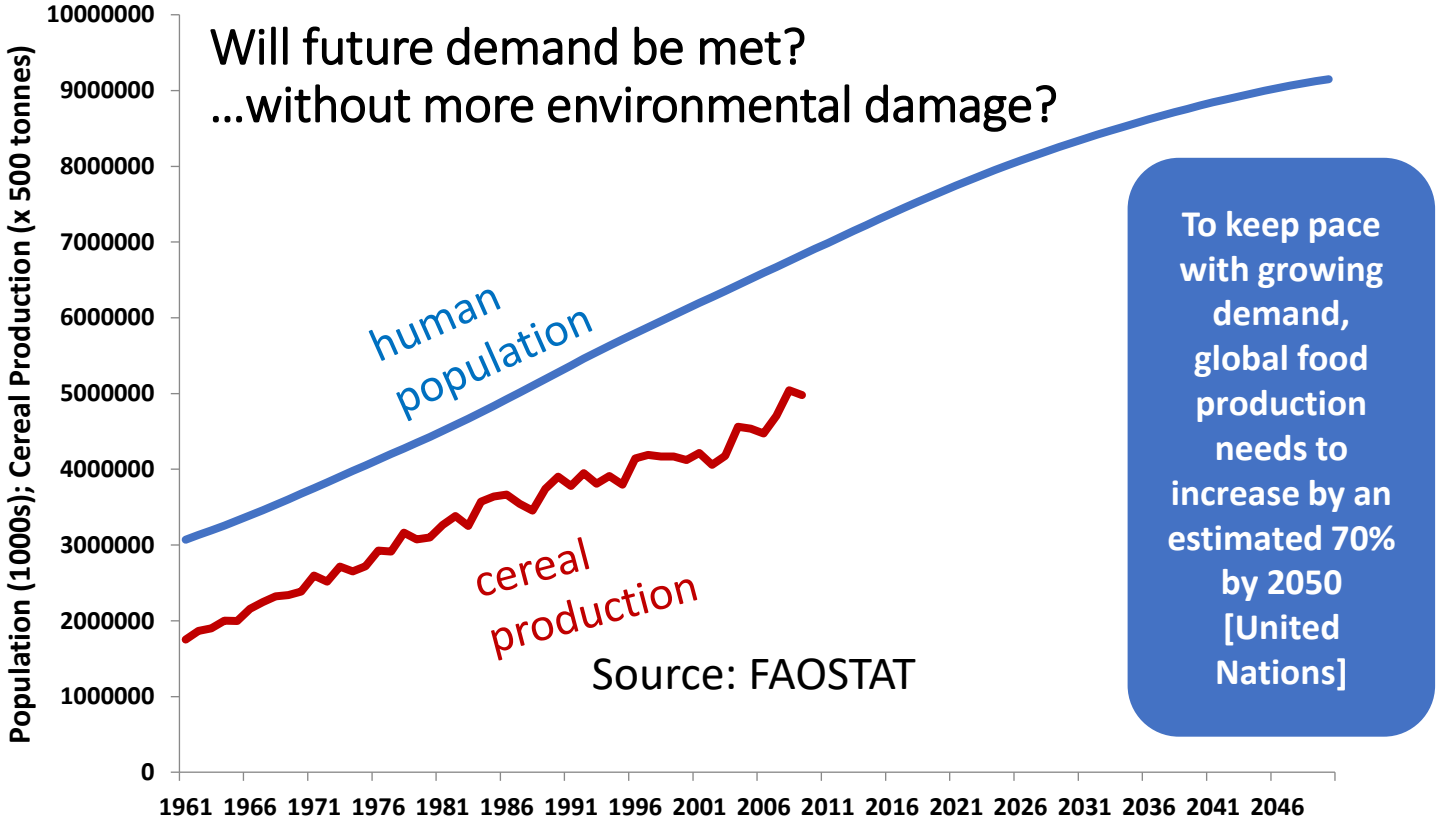
This field has had 5 sprays, last on sat night. Still has this level of infestation.

The Food Security Challenge:

- POPULATION GROWTH
- DEMAND GROWTH
- CLIMATE CHANGE

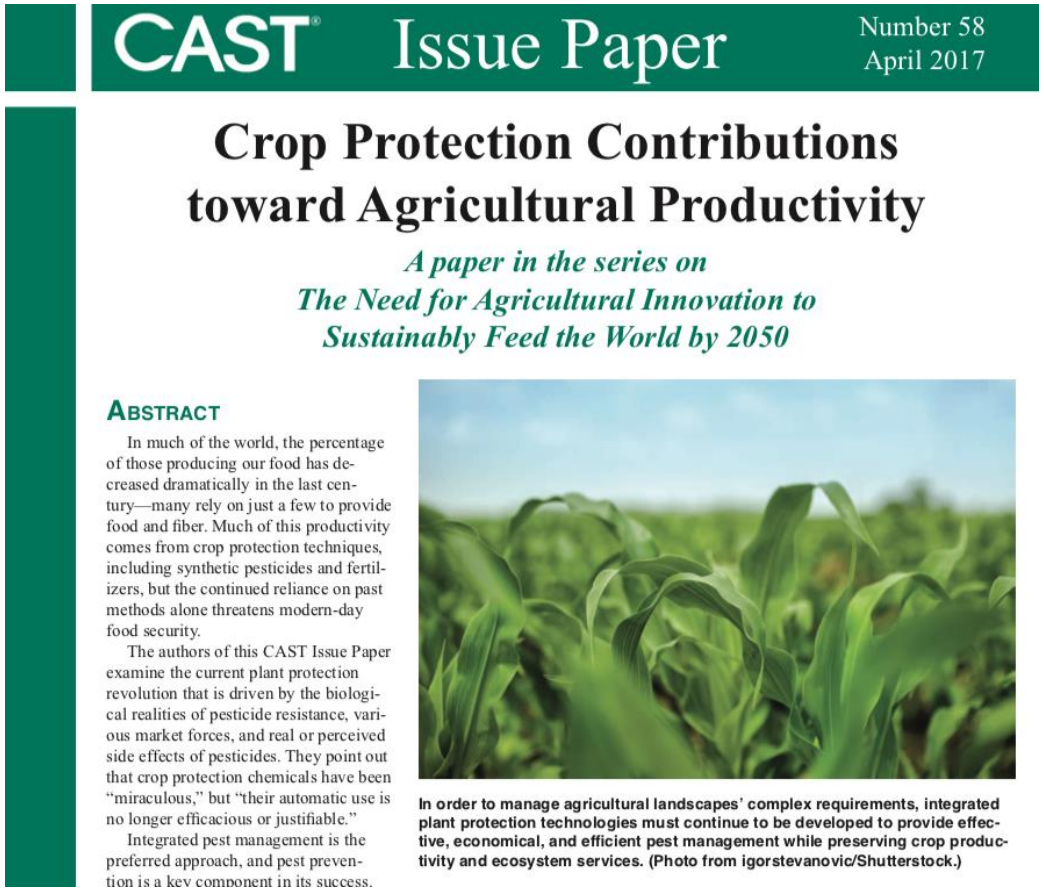
- BIODIVERSITY DECLINE…
- RESOURCE USE e.g. water

- BEDDINGTON – PERFECT STORM
- GREEN REVOLUTION 2



Bruce (2010) *Food Security* 2: 133-141

- Integrated pest management is the preferred approach, and pest prevention is a key component in its success.
- Despite a clear increase in pesticide use, crop losses have not significantly decreased during the past 40 years
- New technologies are becoming important, especially for surveillance and application
- Genetic techniques (such as CRISPR- Cas9, RNAi, marker technology, plant-incorporated protectants, and stacked traits) may fit well into integrated systems



CAST® Issue Paper Number 58 April 2017

Crop Protection Contributions toward Agricultural Productivity

A paper in the series on
The Need for Agricultural Innovation to Sustainably Feed the World by 2050

Abstract

In much of the world, the percentage of those producing our food has decreased dramatically in the last century—many rely on just a few to provide food and fiber. Much of this productivity comes from crop protection techniques, including synthetic pesticides and fertilizers, but the continued reliance on past methods alone threatens modern-day food security.

The authors of this CAST Issue Paper examine the current plant protection revolution that is driven by the biological realities of pesticide resistance, various market forces, and real or perceived side effects of pesticides. They point out that crop protection chemicals have been "miraculous," but "their automatic use is no longer efficacious or justifiable."

Integrated pest management is the preferred approach, and pest prevention is a key component in its success.

In order to manage agricultural landscapes' complex requirements, integrated plant protection technologies must continue to be developed to provide effective, economical, and efficient pest management while preserving crop productivity and ecosystem services. (Photo from igorstevanovic/Shutterstock.)

Ratcliffe *et al.*
CAST issue paper
58 (2017)

"A key question arises as to whether the use of plant protection products can be reduced while maintaining or increasing yields." **i.e will there be yield decline?**

European Parliament

The future of crop protection in Europe

"*Innovation by the industry, together with fundamental and applied research by universities and research institutes create the opportunities for improving crop protection techniques*."

- Mechanical techniques
- Plant breeding
- Biocontrol
- Induced resistance
- Applying ecological principles in diversified systems
- Precision agriculture
- Plant protection products

STUDY

Panel for the Future of Science and Technology

EPRS | European Parliamentary Research Service

Scientific Foresight Unit (STOA)

PE 656.330 – February 2021

European Parliamentary Research Service, 2021

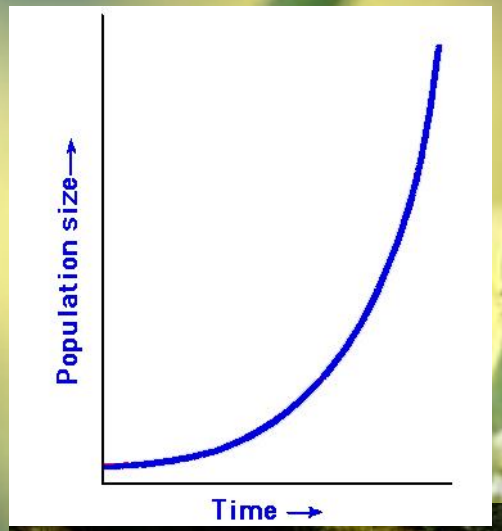
EN

New directions for 21st Century Agriculture

Royal Society: *"There is a pressing need for the '**sustainable intensification**' of global agriculture in which yields are increased without adverse environmental impact and without the cultivation of more land".*

Royal Society (2009) Policy document 11/09

The Crop Protection Challenge:



New Options are needed:

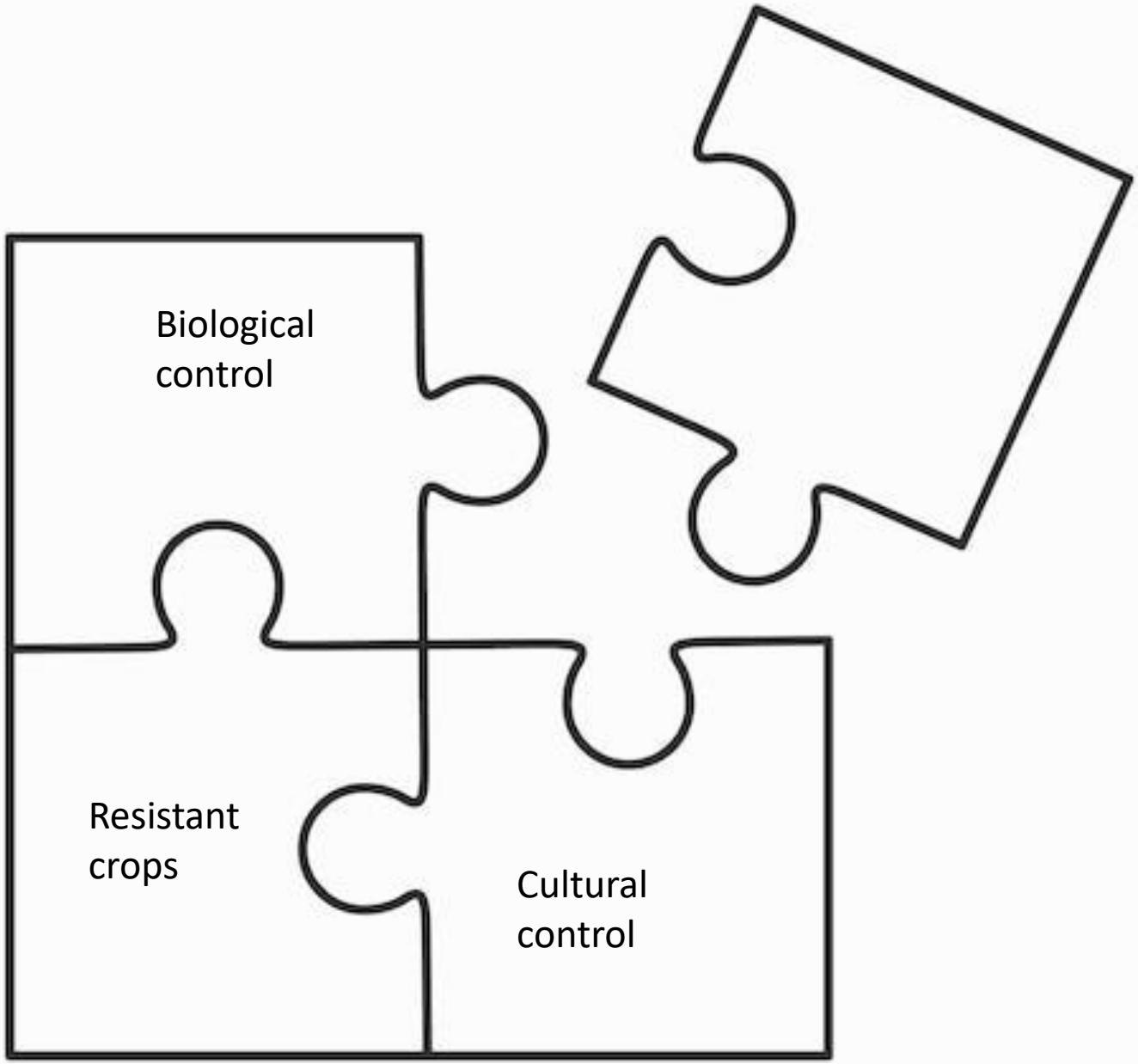
“system redesign”


The innovation process to create new options starts with research

Research opportunities

- Can crop environments be made less suitable for pests?
- Can plant resistance to pests be improved?
- Can impact of natural enemies of pests be increased?

“system redesign”



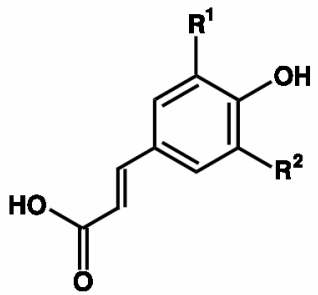
Orange wheat blossom midge

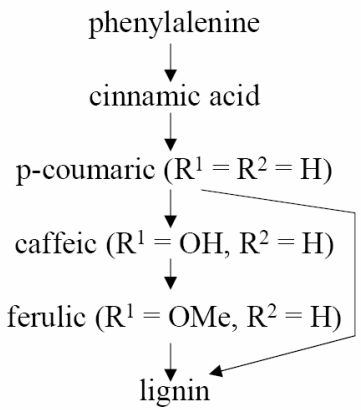
Orange wheat blossom midge,
Sitodiplosis mosellana

OWBM Resistant wheat varieties

Females lay eggs, but larvae die when they start to feed

A wound plug is formed at the feeding site due to lignification

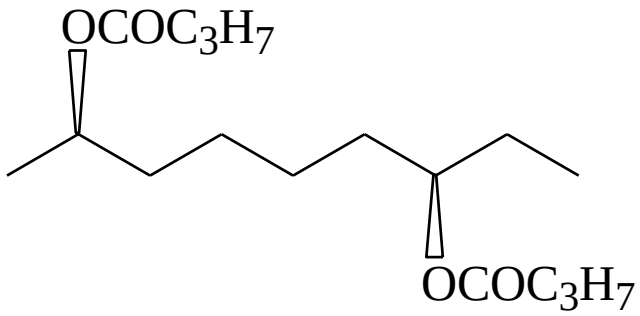




About 40% of UK wheat is now resistant to orange wheat blossom midge

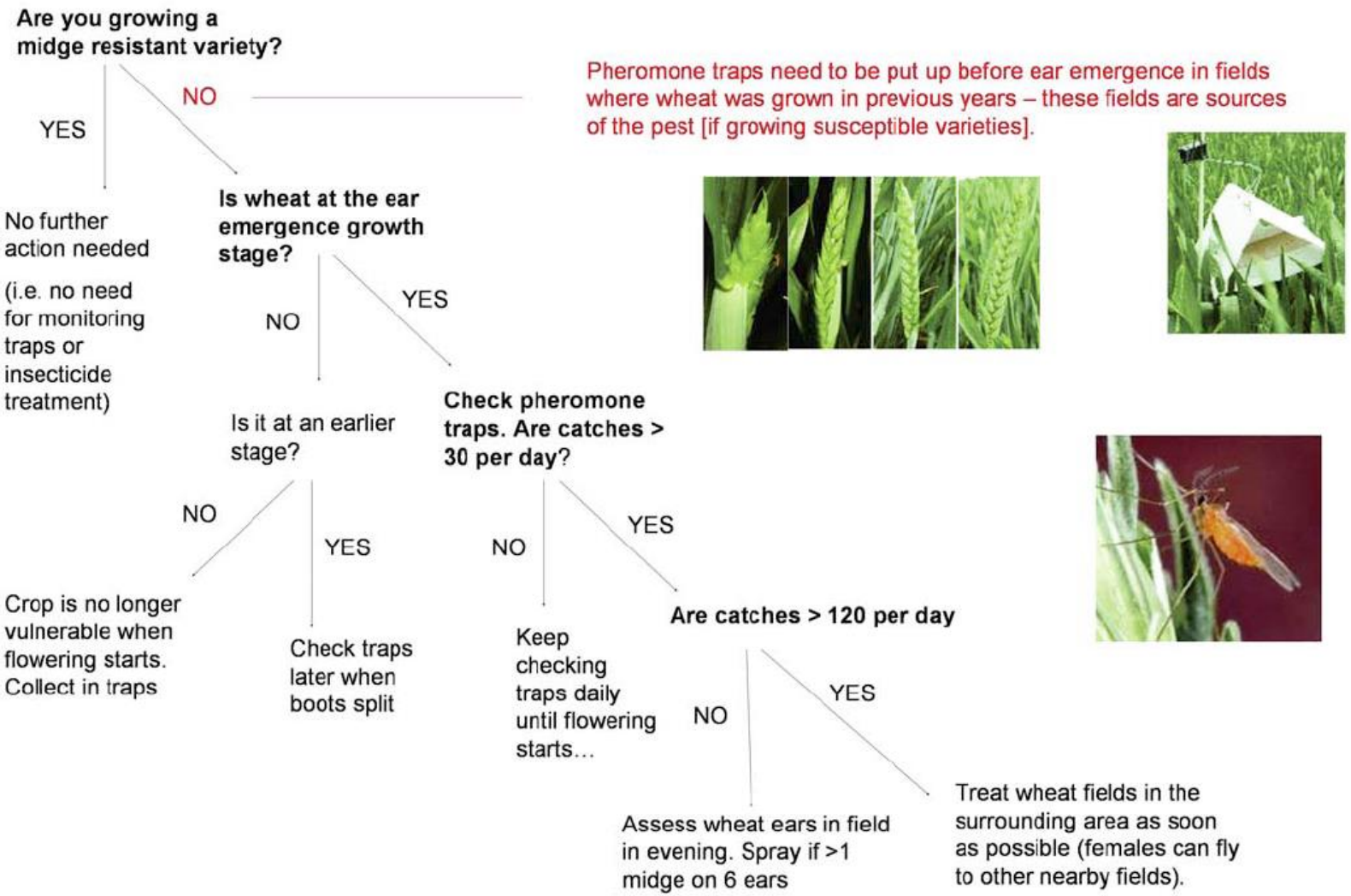
Decision support system for OWBM

2,7-nonanediyl dibutyrate



Bruce et al. (2007) *Pest Man. Sci*. 63: 49

Decision support system for OWBM



Bruce & Smart (2009) *Outlooks Pest Management* 20: 89-92

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Companion cropping

Fall armyworm, *Spodoptera frugiperda*, damage to maize in Kenya

Companion cropping

Fall armyworm, *Spodoptera frugiperda*, damage to maize in Kenya

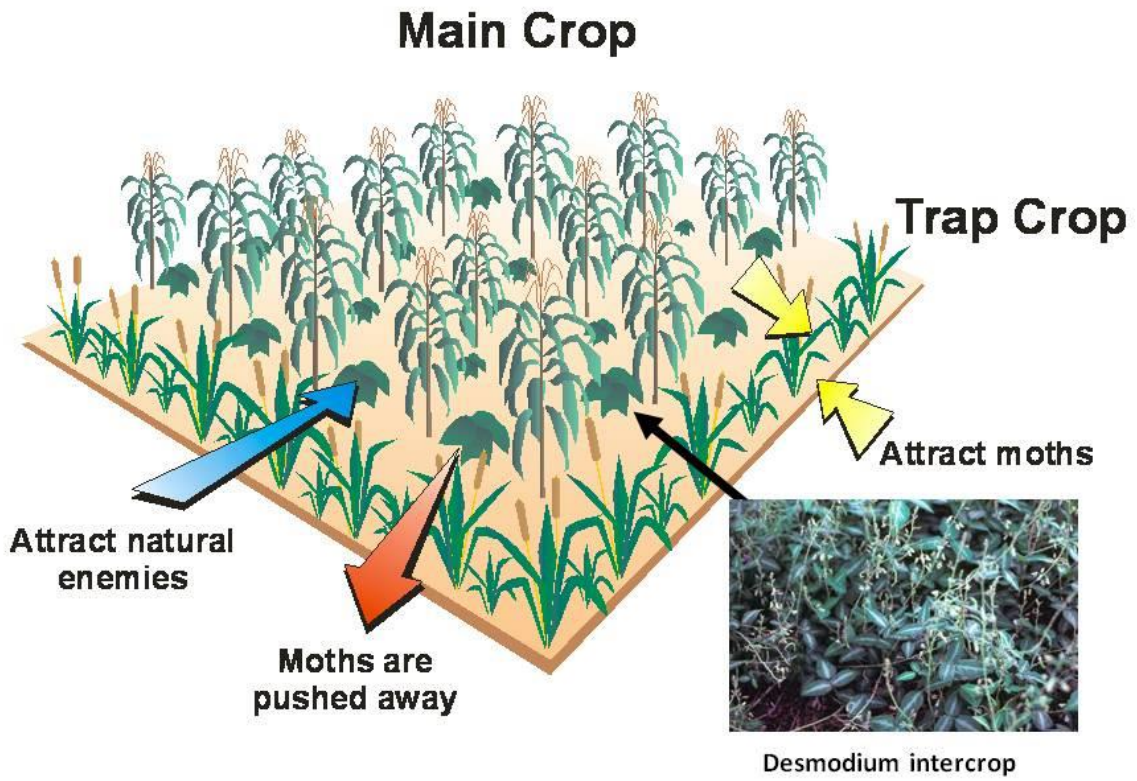
Amanuel Tamiru

Islam Sobhy

Keele University

icipe

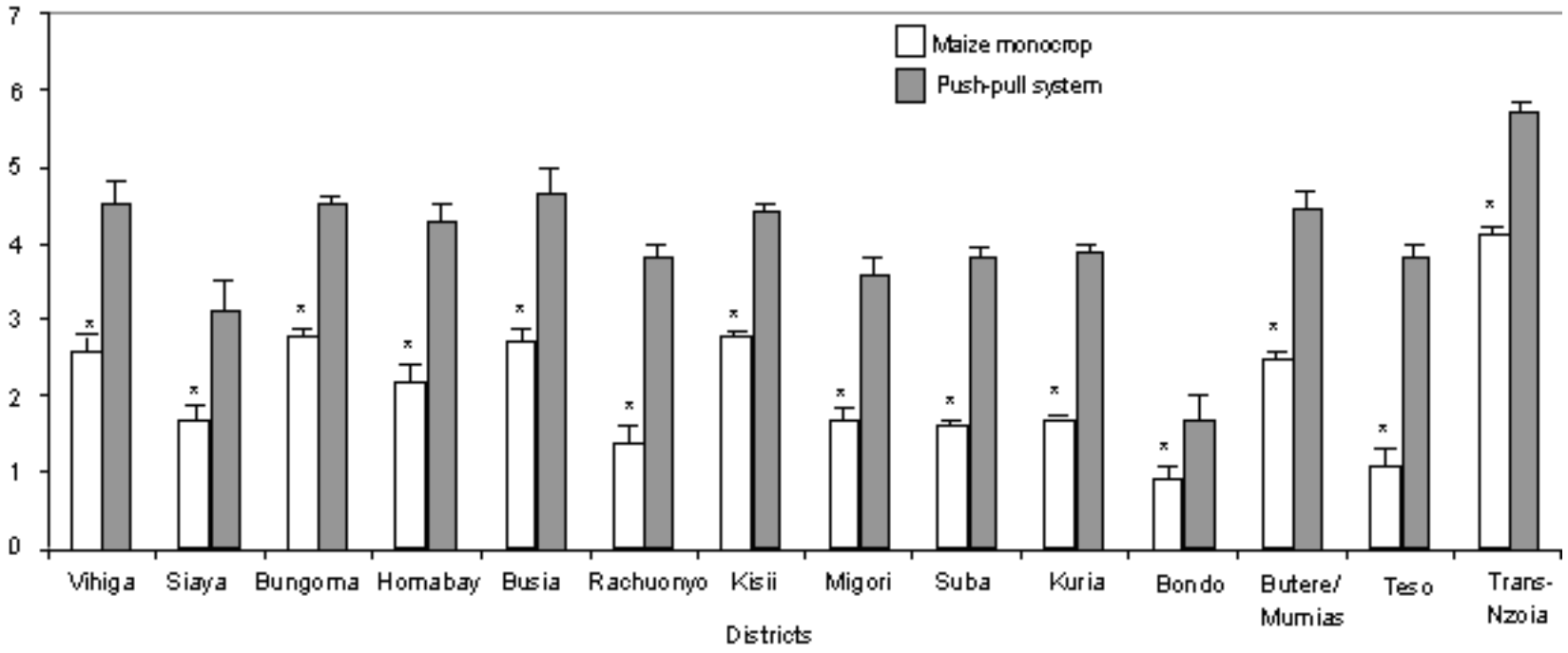
Cultural control



In the “push-pull” system companion plants release chemicals to repel pests and suppress weeds

Push-pull in Kenya

Maize yields doubled with push-pull



Within a district, bars marked by asterix (*) are significantly lower ($p<0.05$, t-test)

Keele University icipe


Push-Pull companion cropping can prevent fall armyworm damage to crops
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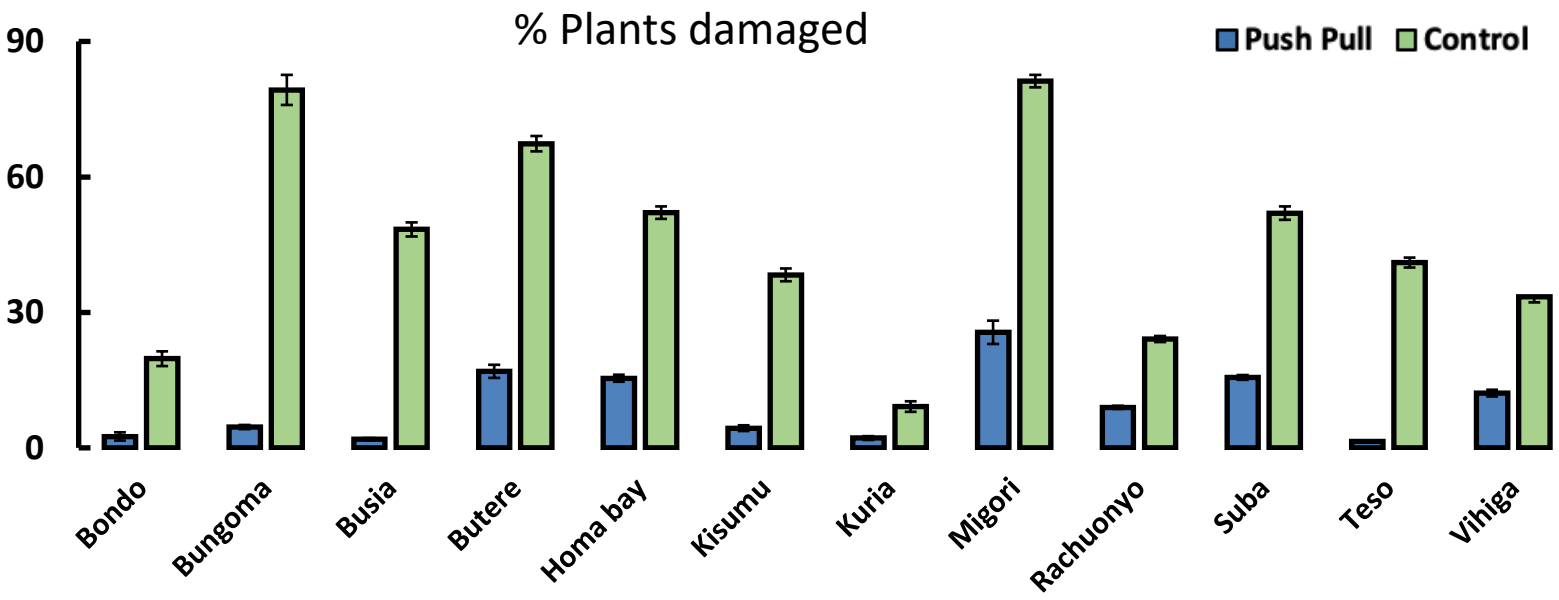
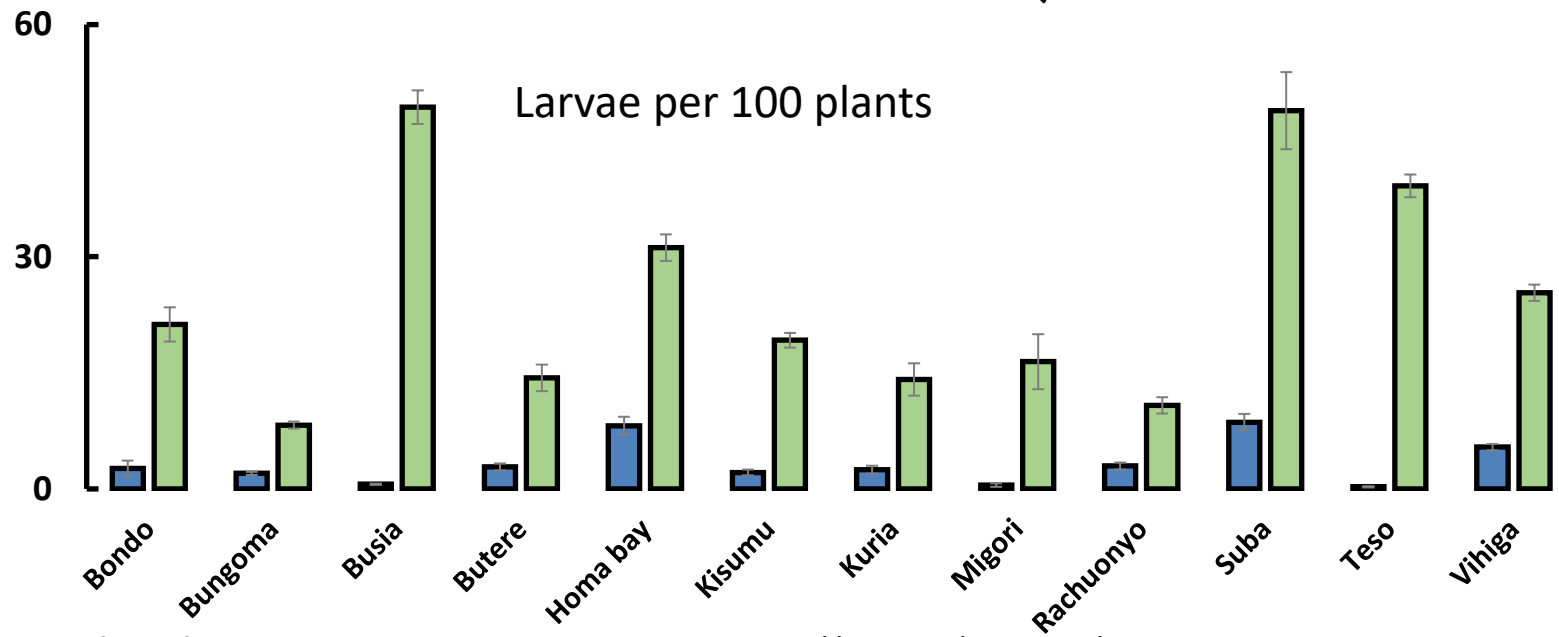
icipe

Insect sampling in farmers' fields, Kenya 2020, Long Rains season





Push Pull plots
Intercrop: Greenleaf *Desmodium intortum*
Border crop: *Brachiaria* cv. Mulato II

30 smallholder farms per district -> at each farm treatments in two plots, push pull technology and monocrop (control)

Sobhy *et al.* (2022) Frontiers in Ecology and Evolution https://doi.org/10.3389/fevo.2022.883020

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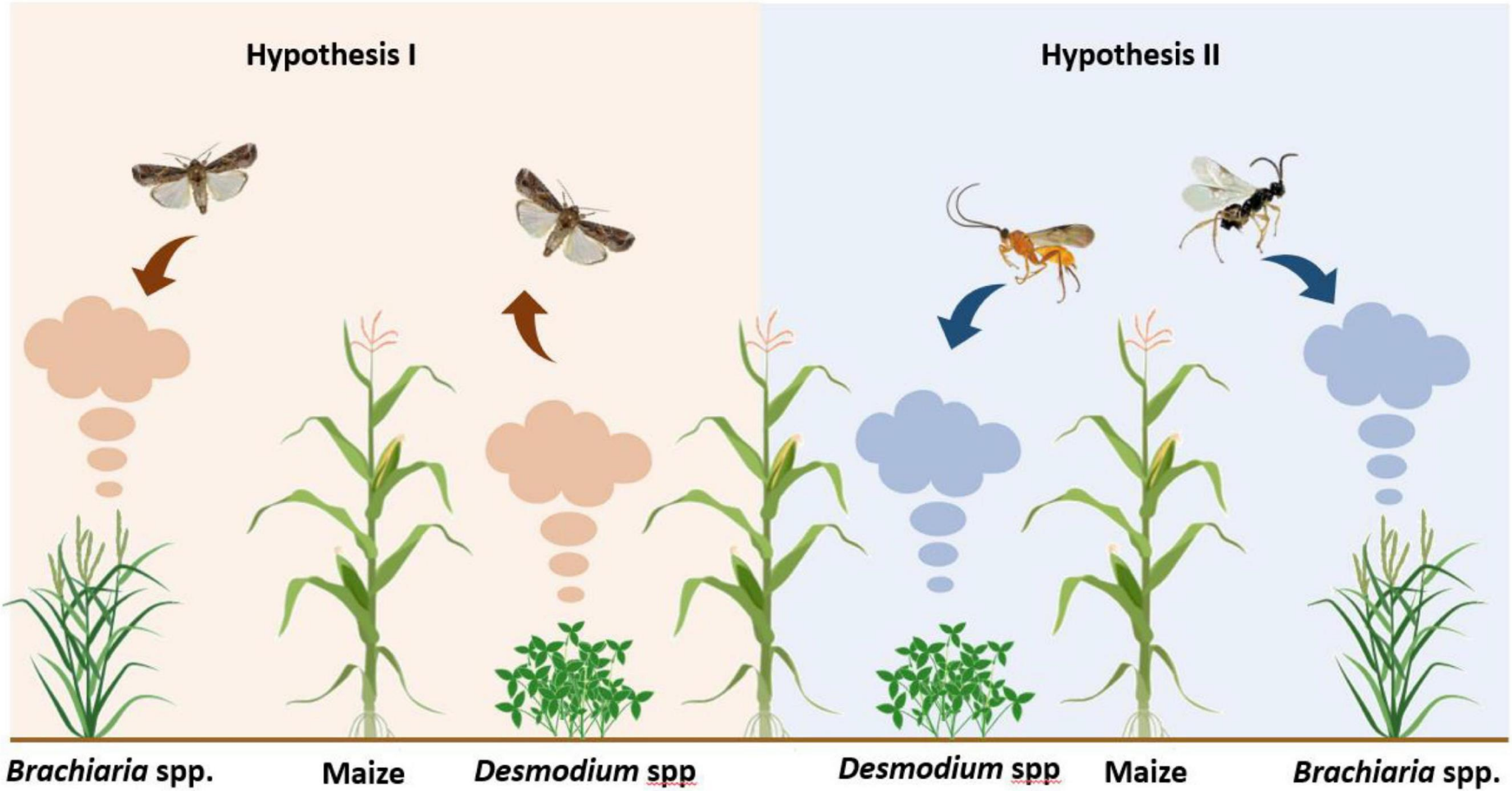
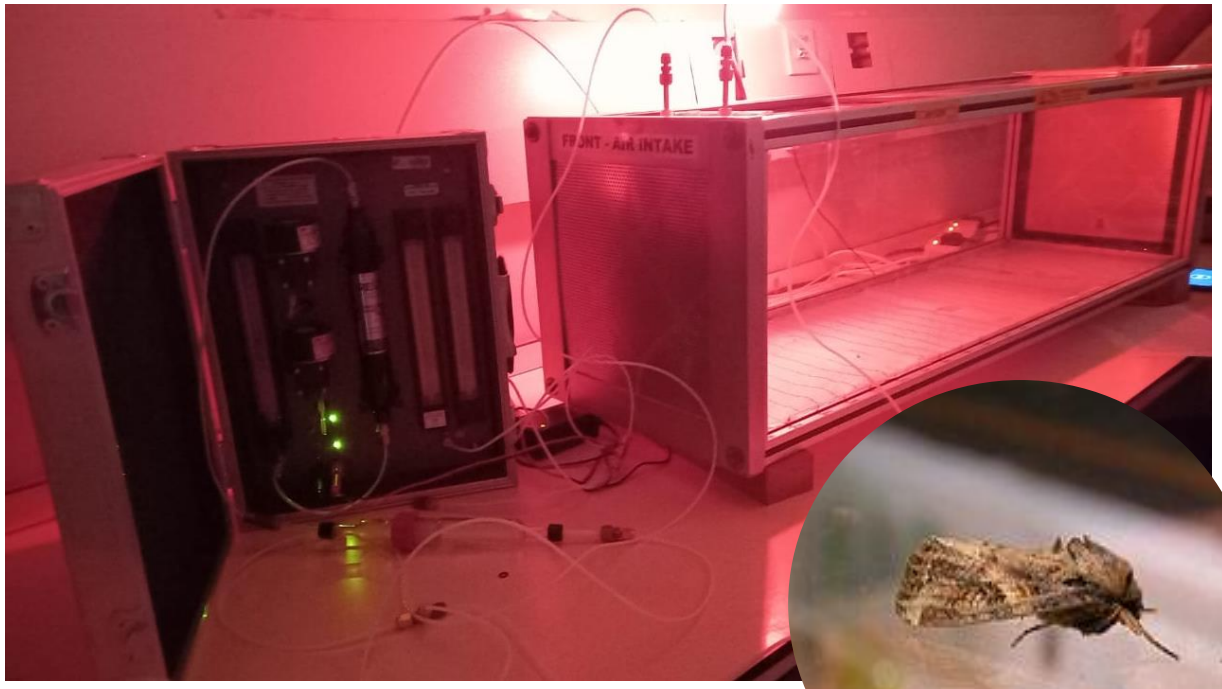
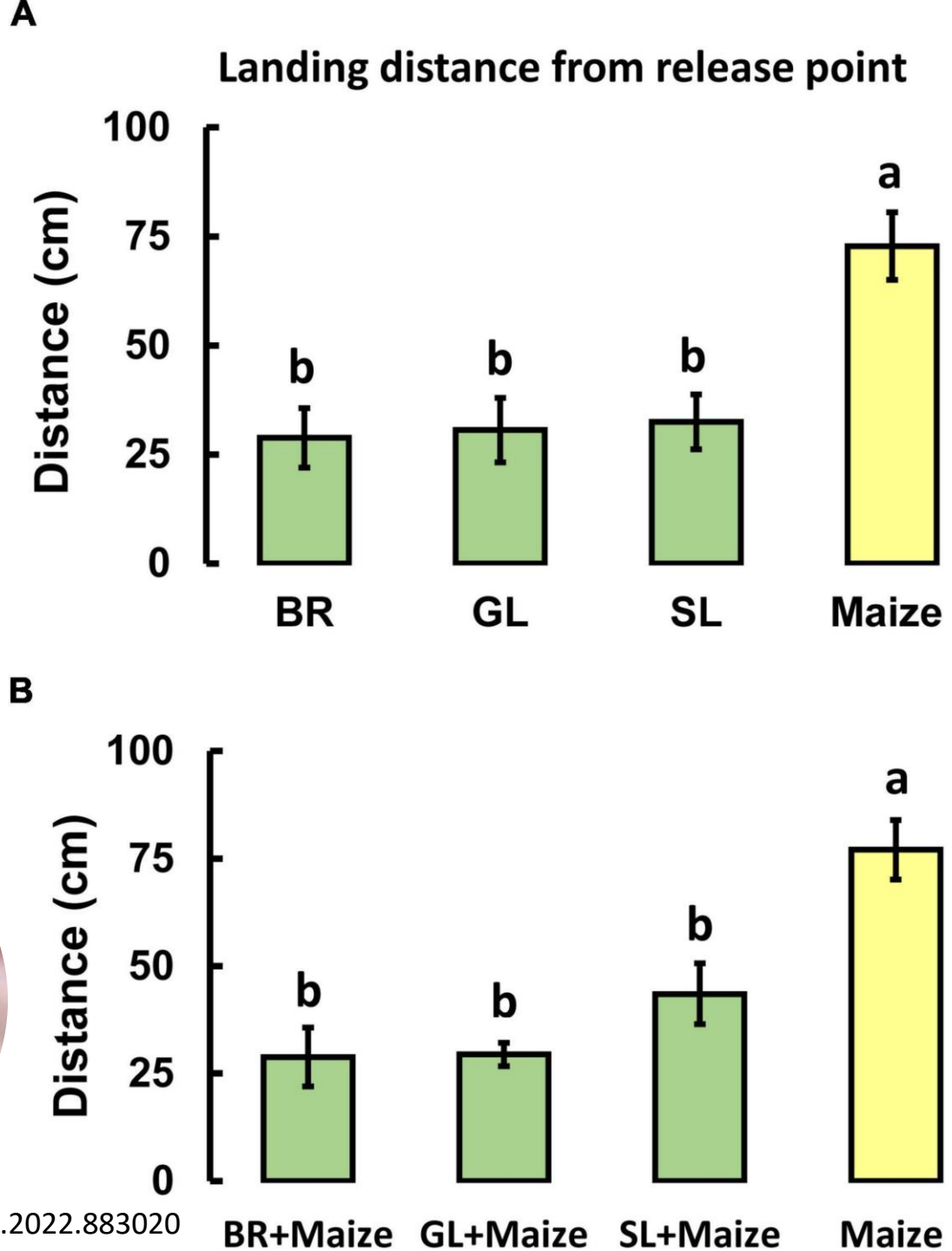

Hypothesis I
Hypothesis II
Brachiaria spp.
Maize
Desmodium spp
Desmodium spp
Maize
Brachiaria spp.

Volatiles from companion plants
reduced upwind flight of
moths in wind tunnel





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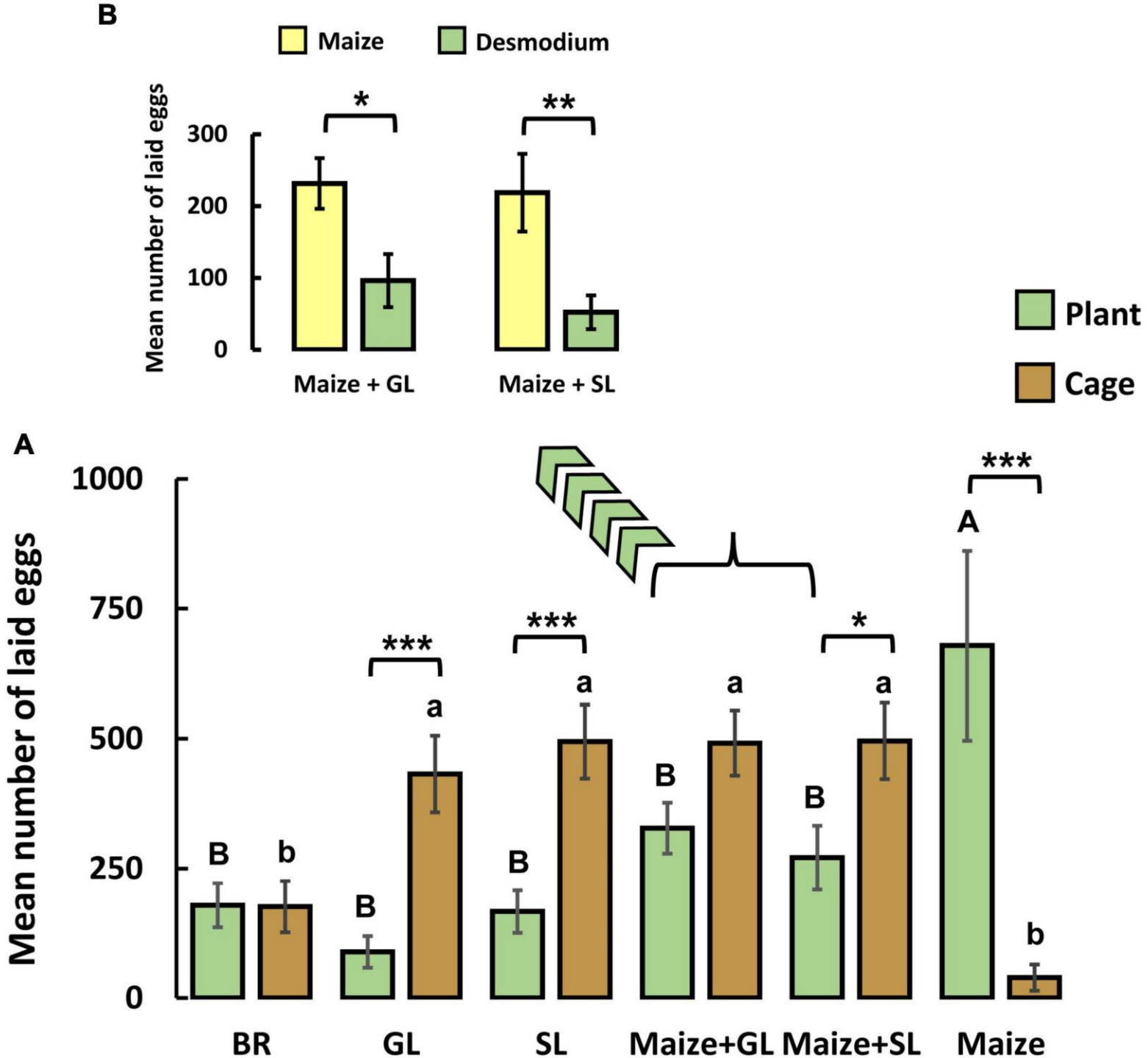
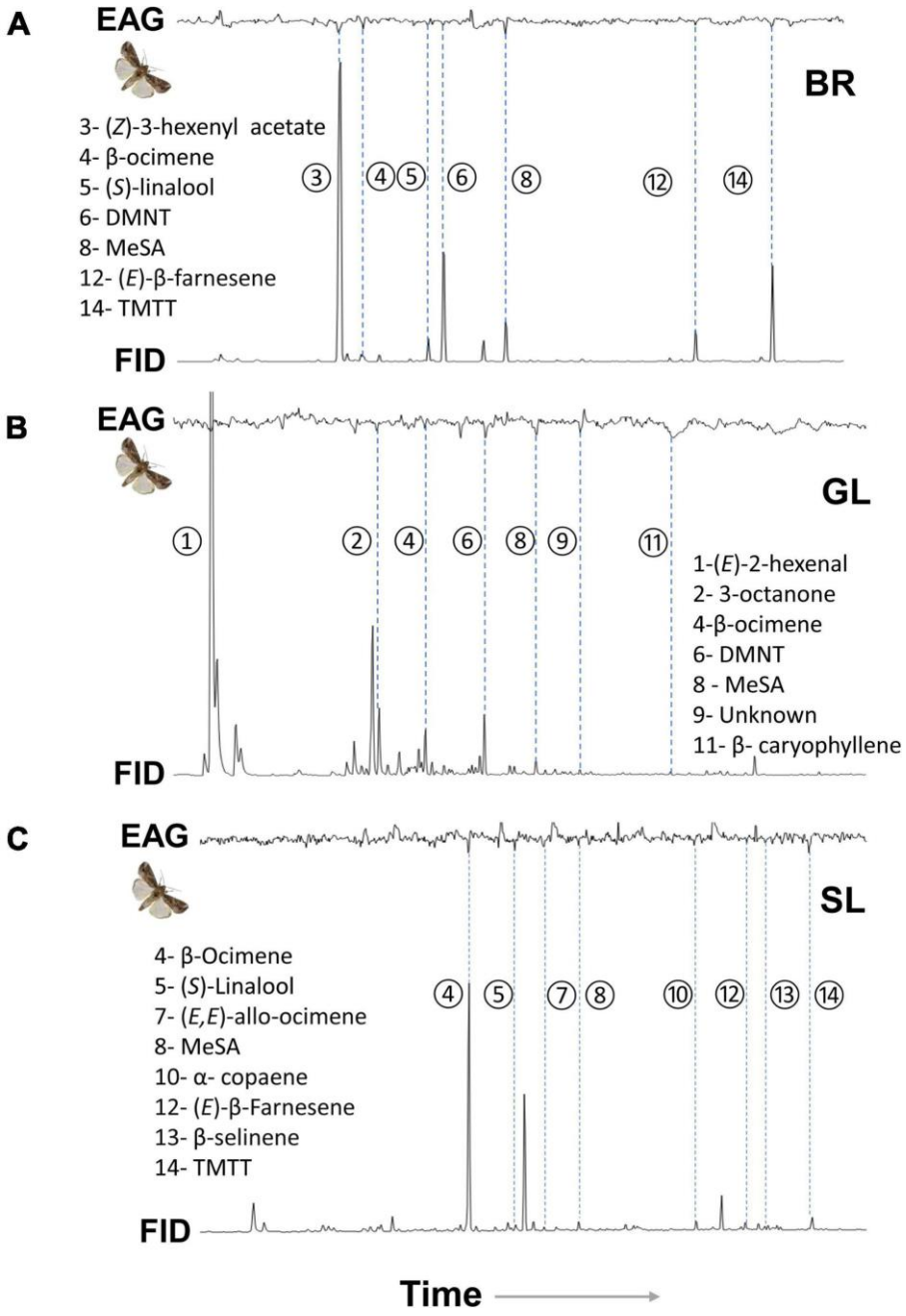
Volatiles from companion plants reduced egg laying by fall armyworm moths



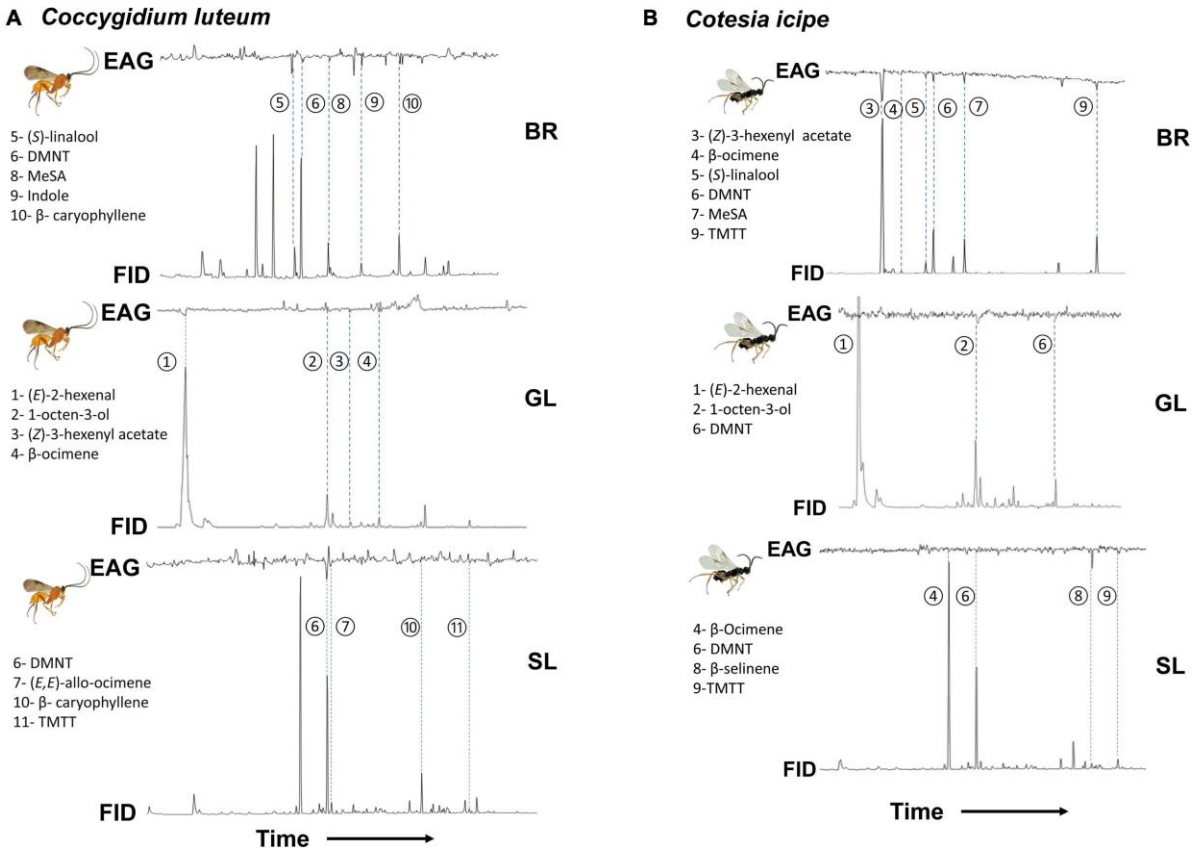
Sobhy *et al.* (2022) Frontiers in Ecology and Evolution

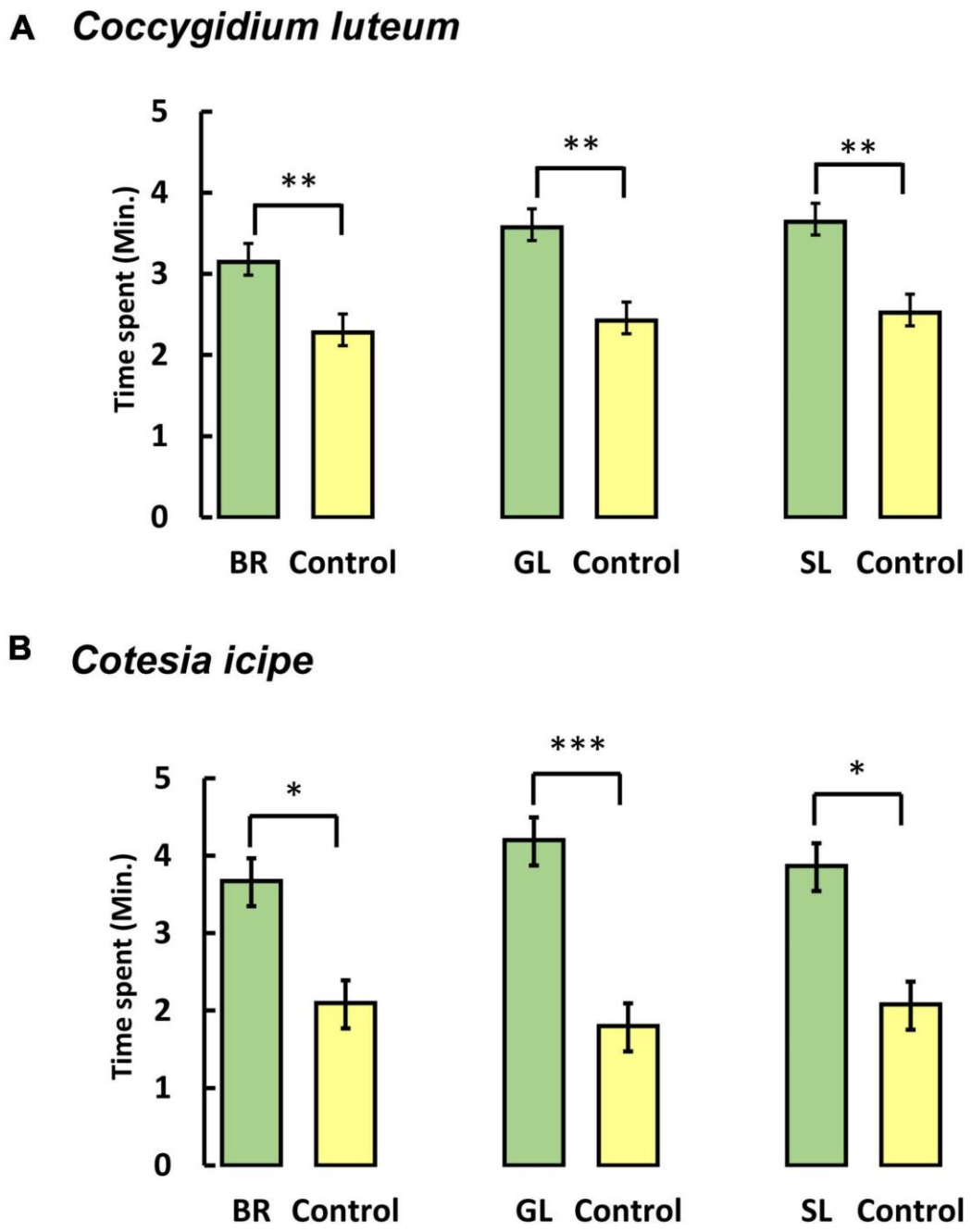
Bioactive compounds identified using electroantennogram recordings



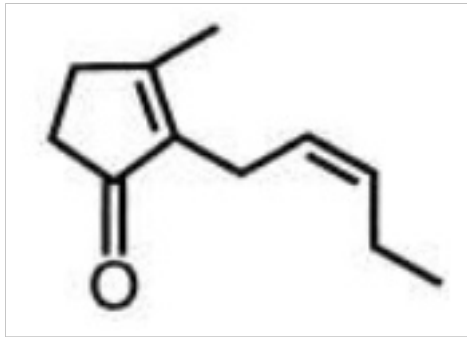
Sobhy *et al.* (2022) Frontiers in Ecology and Evolution https://doi.org/10.3389/fevo.2022.883020

Volatiles from companion plants were attractive to parasitoid wasps

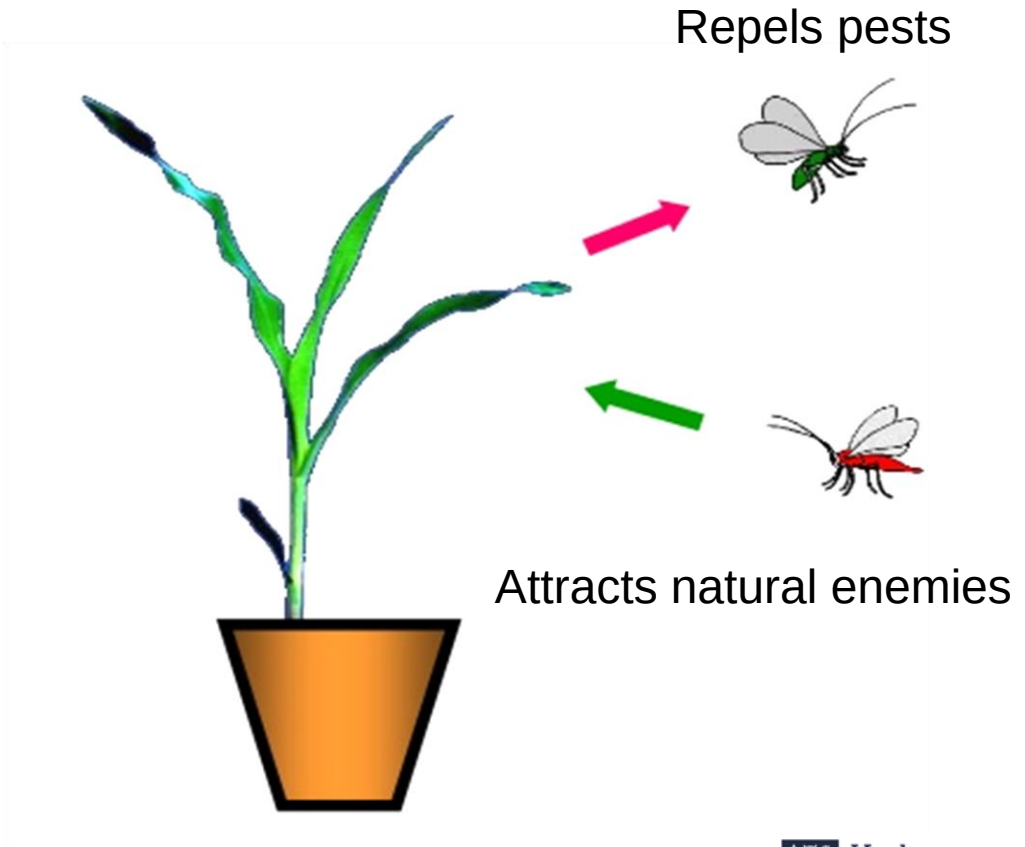




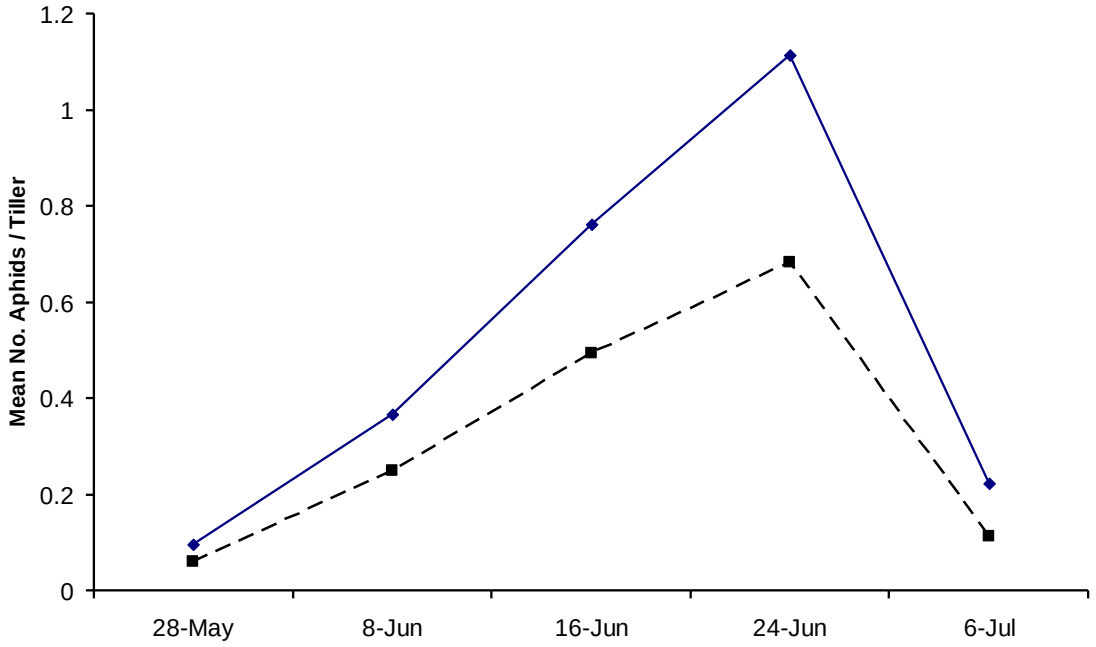
cis-Jasmone

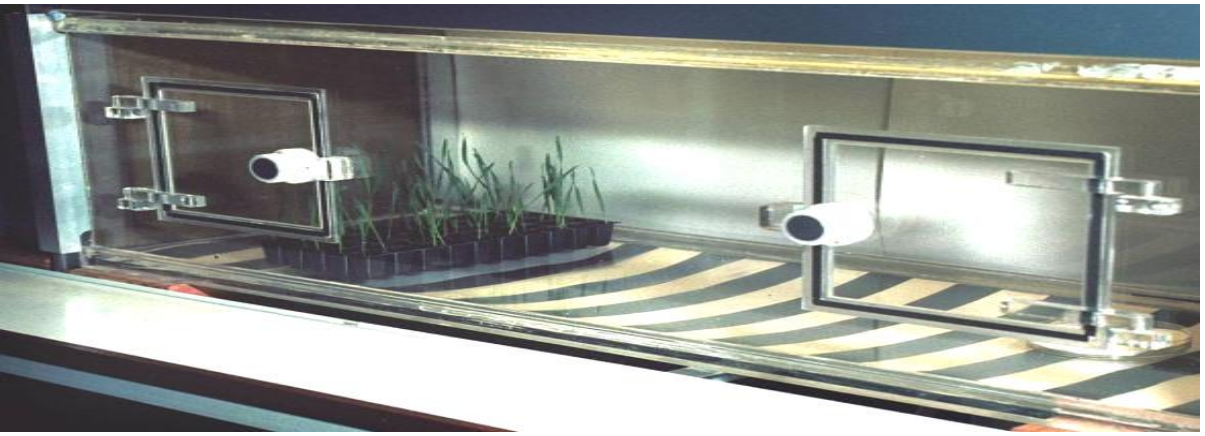


- Stress related volatile plant activator that induces defence mechanisms
- Non-toxic
- No residue left as it is volatile

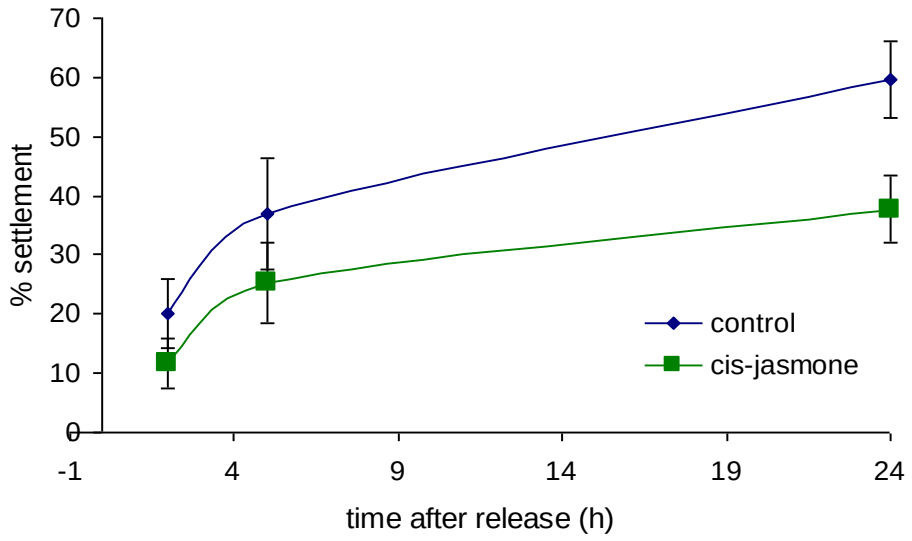


cis-Jasmone plant defence activator



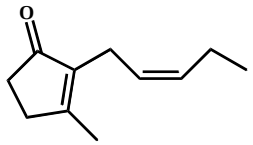


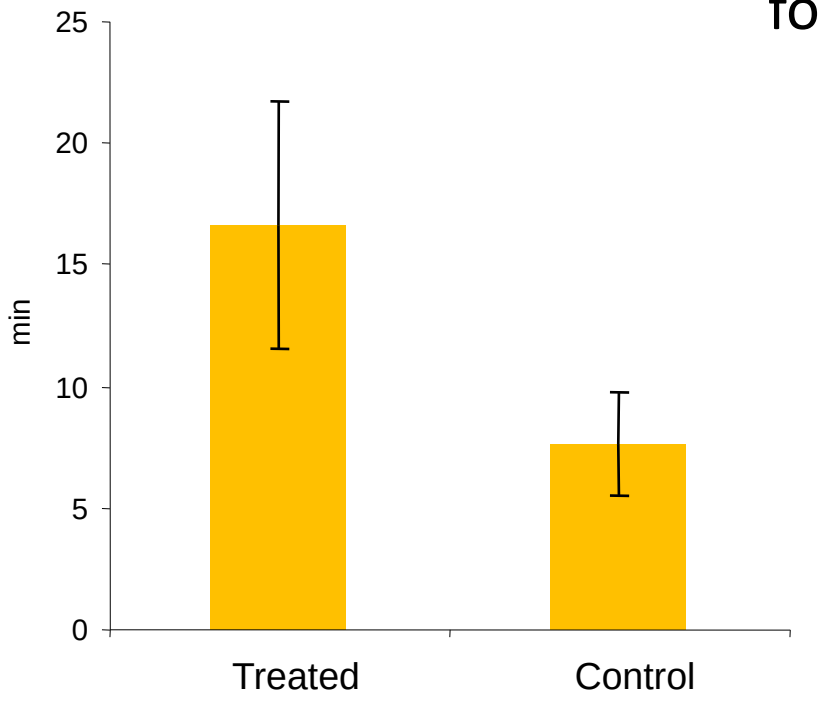
Reduces aphid settlement



Bruce et al. 2003 Pest Management Science 59 1031

cis-Jasmone plant defence activator



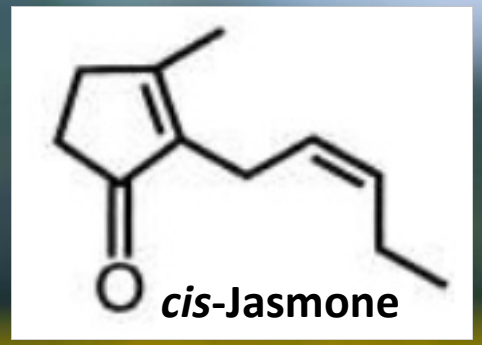


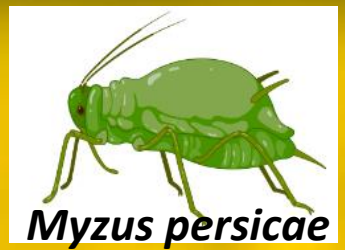
Increases parasitoid foraging

significantly longer time spent on induced plants

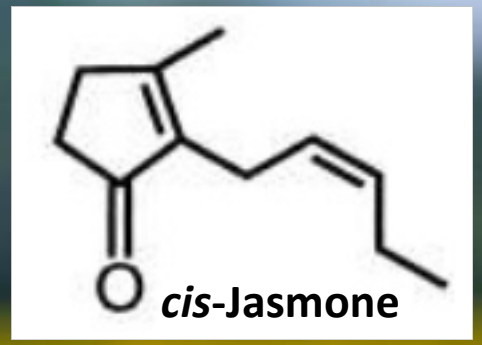
Bruce et al. 2008 PNAS 105: 4553-4558

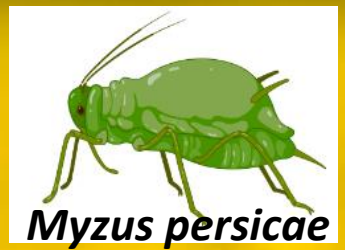
cis-Jasmone plant activator

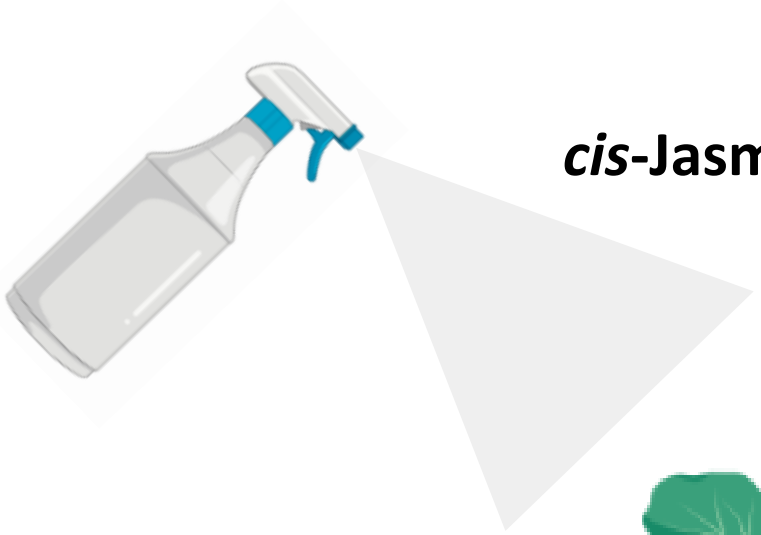




cis-Jasmone plant activator

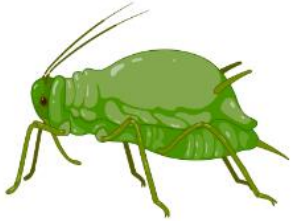






***cis*-Jasmone**

Diaeretiella rapae
Natural enemy (parasitoid)



Myzus persicae
Plant Pest

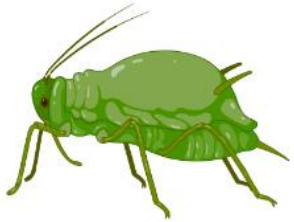
Brassica

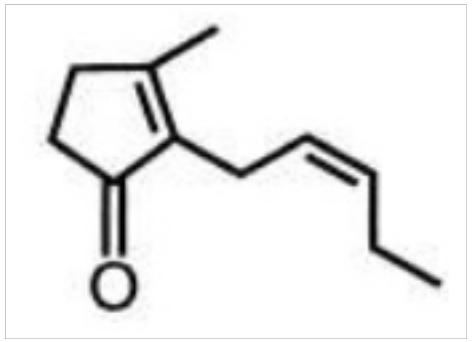
Brassica napus
Brassica oleracea
Brassica rapae

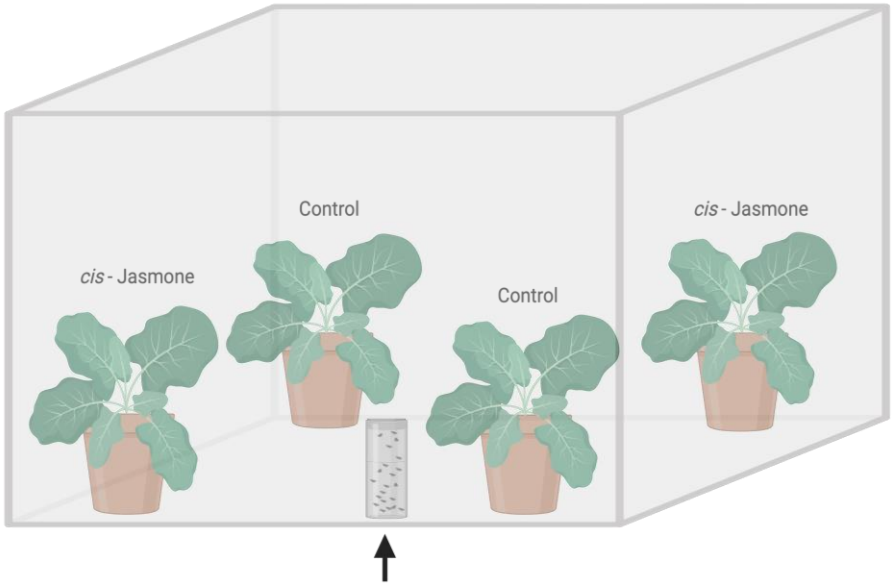
Ali et al. (2021) Frontiers in Plant Science 12: 711896

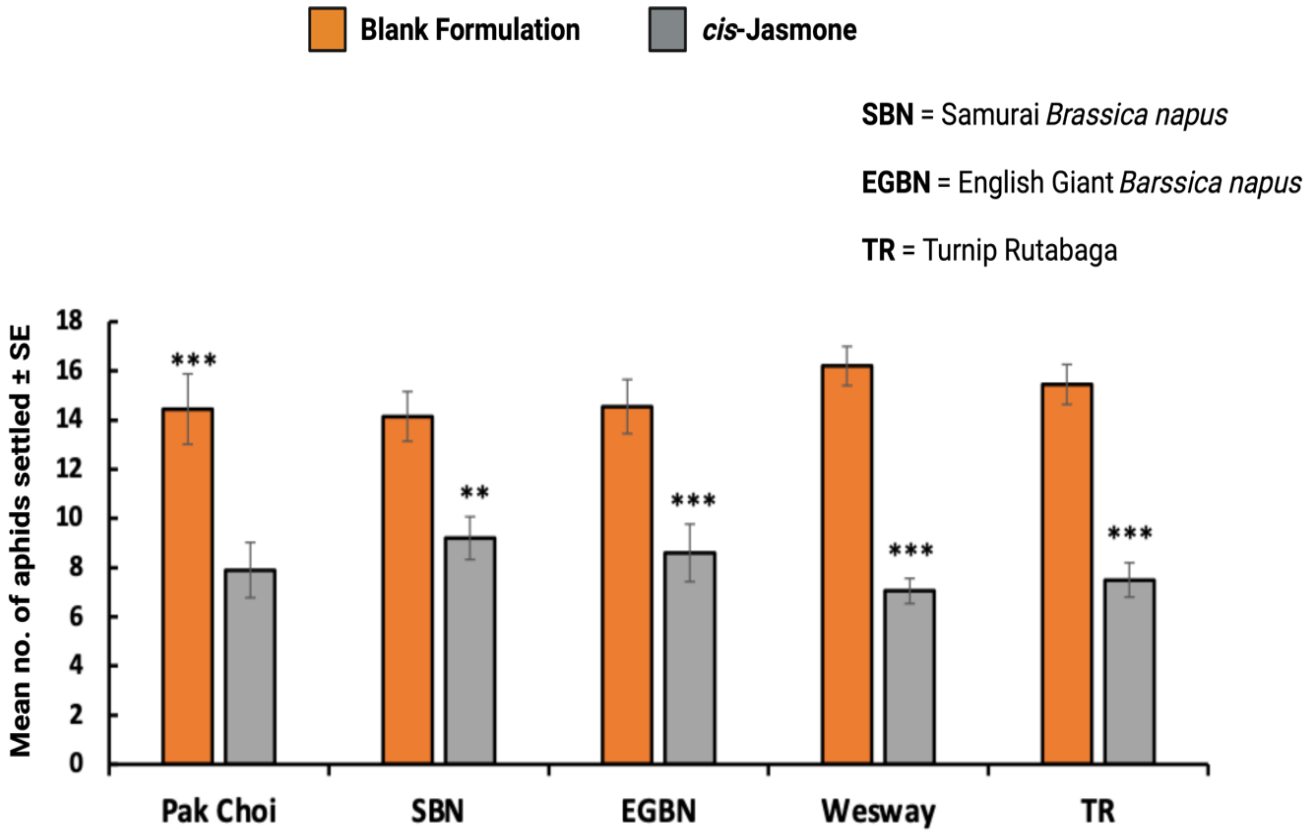
Keele University

cis-Jasmone treatment reduced aphid settlement



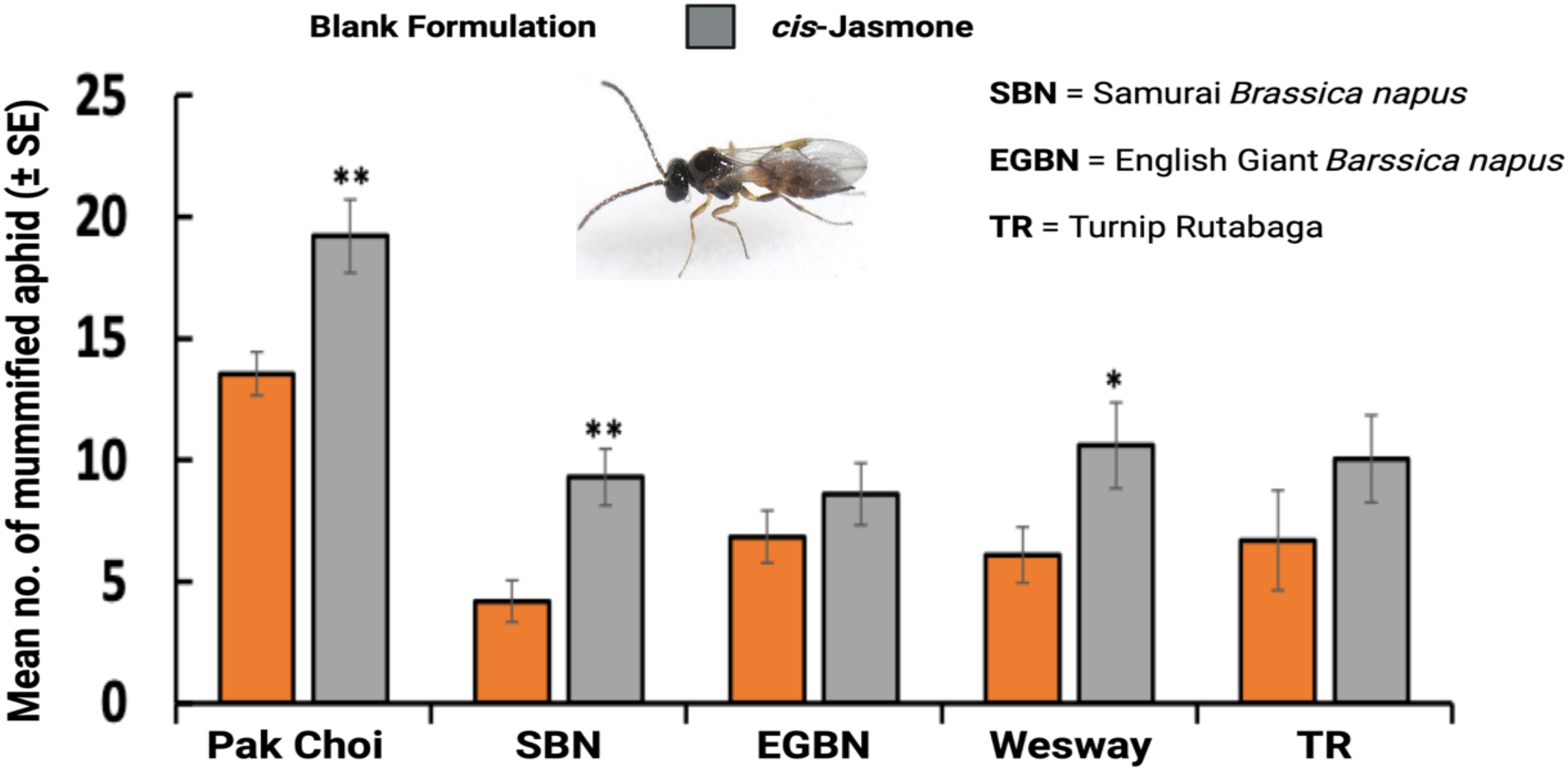






Ali et al. (2021) Frontiers in Plant Science 12: 711896

cis-Jasmone treatment increased parasitism



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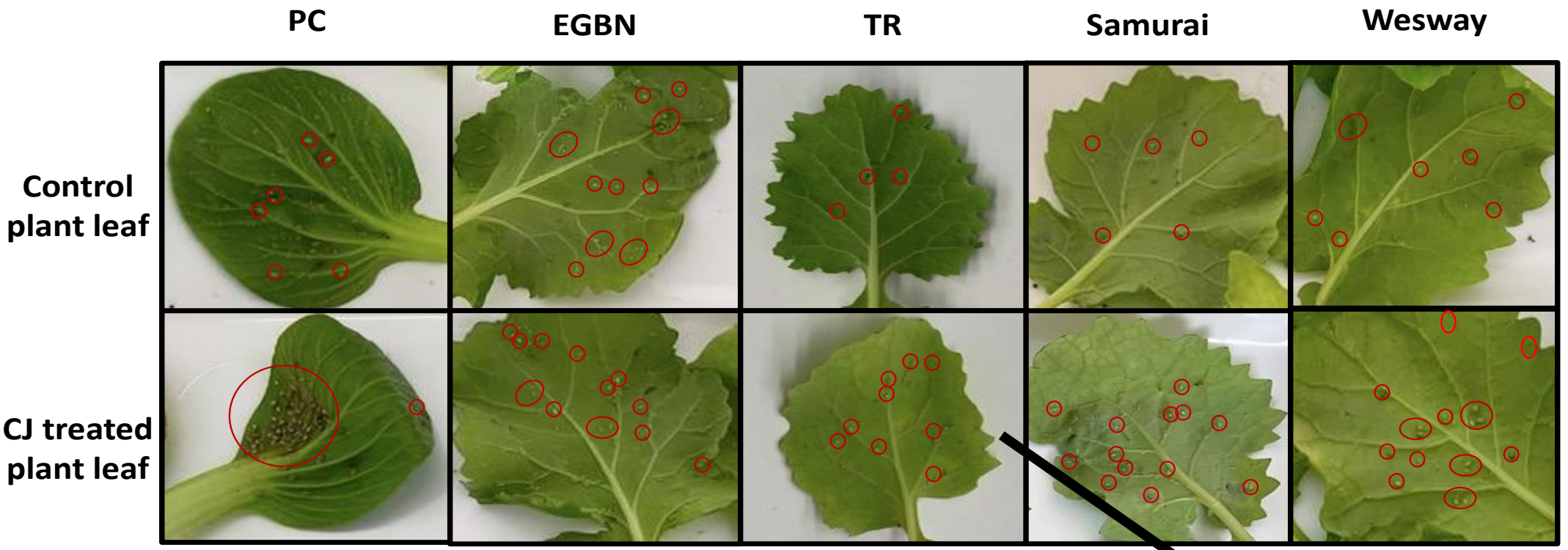

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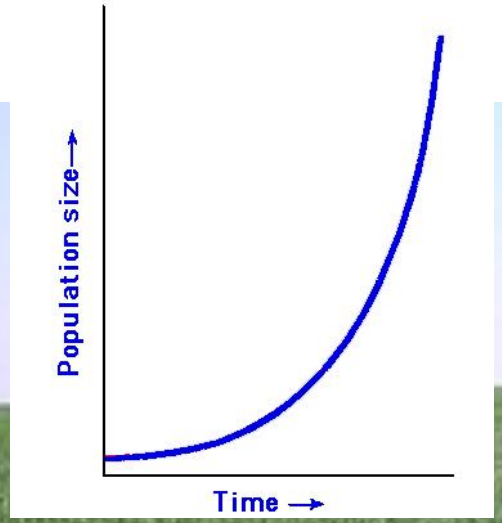

Population size
Time

“A truly extraordinary variety of alternatives to the chemical control of insects is available. Some are already in use and have achieved brilliant success. Others are in the stage of laboratory testing. Still others are little more than ideas in the minds of imaginative scientists, waiting for the opportunity to put them to the test. All have this in common: they are biological solutions, based on the understanding of the living organisms they seek to control and of the whole fabric of life to which these organisms belong. **Specialists representing various areas of the vast field of biology are contributing—entomologists, pathologists, geneticists, physiologists, biochemists, ecologists—all pouring their knowledge and their creative inspirations into the formation of a new science of biotic controls**.”

Carson, 1962

Is transfer of genes from wild relatives acceptable?

(image courtesy of Jonathan Jones, Sainsbury Laboratory)

Choosing between food security and biodiversity is an unacceptable choice,

we need to find ways to achieve both

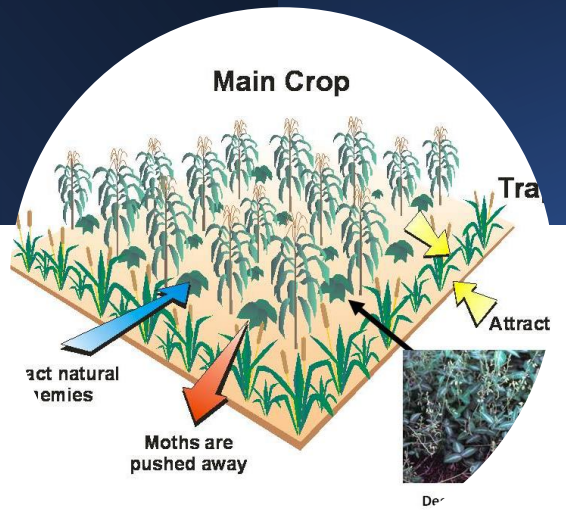
New directions for 21st Century Agriculture

Royal Society: *"There is a pressing need for the '**sustainable intensification**' of global agriculture in which yields are increased without adverse environmental impact and without the cultivation of more land".*

A second green revolution relies more on knowledge than high levels of inputs?

Royal Society (2009) Policy document 11/09

Developing new tools for crop protection:



- Resistant crop varieties
- Natural enemies to combat insect pests
- Cultural methods to reduce infestation
- Monitoring systems to forecast risk to crops and rationalise pesticide use

Thank you

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