Soil health is the capacity of soil to function as a living system, with ecosystem and land use boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health” – FAO (2008)
Soil constituents and health

Only "living" things can have health, so viewing soil as a living ecosystem reflects a fundamental shift in the way we care for our soils.

Organic matter depletion

- Silt loam soils in Missouri showed a decline in organic matter from 3.9% to 2.6% over a 60 year period.
- Affects biological and physical aspects of the soil.
- This corresponded to a change in plastic limit moisture content from 27% to 22% and a less ideal working range.

After: Baver et. al., 1972
For the Government to meet its ambition for all soils to be managed sustainably by 2030, and to ensure agricultural resilience and minimise the effects of climate change, urgent action is required to reverse this trend and increase carbon levels in all soils.

*Every ton of carbon* maintained in soil gives *greater flexibility* to the rest of the economy in meeting our carbon budgets.

Calling for a **1% increase in SOM/year** for 20 years (i.e. from 3% > 3.6%)

### Tillage Options

- **Conventional**
  - Overall disturbance and inversion
- **Deep**
  - Overall disturbance
- **Shallow**
- **Minimum tillage**
  - Overall disturbance to a shallow depth
- **Strip tillage**
  - Till/plant a specific zone
- **Direct drill**
  - Plant directly into the soil
- **No-Till**
  - "Reduced tillage"
Potential effects in converting from tillage to “No-till”

Increase

Decrease

Current position with tillage

Time - years

Earthworm numbers
Soil structure
Pest protection
Fertilizer requirements
Crop Yield
Plant ownership cost
Total cost/ha
Tractor hours/year

After: Carter, 1994

Random Traffic Problems

Extensive areas of the field are exposed to trafficking

- Random Traffic + plough = 85% covered
- Minimum Tillage = 65% covered
- Direct Drilling = 45% covered

Wheat
Czech Republic

Potato establishment
Shropshire: 84%

Kroulik, Mstiewicz, White and Godwin, 2012

Kroulik et al, 2011
Controlled traffic and soil structure

<table>
<thead>
<tr>
<th>Soil structure score after broccoli harvest</th>
<th>Conventional traffic &amp; tillage</th>
<th>Controlled traffic</th>
<th>40 year pasture fence line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score 1 - 2</td>
<td>3 - 4</td>
<td>7 - 8</td>
<td>9 - 10</td>
</tr>
</tbody>
</table>

Soil structure score

Aim: To compare the effects of alternative traffic and tillage systems on crop yield, energy and economics, water holding and infiltration rates over an extended period circa 10 years.

Traffic and Tillage Systems Study

3 x 3 factorial design

9 treatments replicated in 4 randomised complete blocks = 36 plots in total (each 4m wide)

<table>
<thead>
<tr>
<th>Traffic Tillage</th>
<th>Random Traffic Farming</th>
<th>Low Ground Pressure</th>
<th>Controlled Traffic Farming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep tillage</td>
<td>250mm</td>
<td>250mm</td>
<td>250mm</td>
</tr>
<tr>
<td>Shallow tillage</td>
<td>100mm</td>
<td>100mm</td>
<td>100mm</td>
</tr>
<tr>
<td>Zero tillage</td>
<td>0mm</td>
<td>0mm</td>
<td>0mm</td>
</tr>
</tbody>
</table>

After: Smith, Misiewicz, Chaney, White and Godwin, 2013/2014
Crop condition on 29th May 2013

Zero tillage has a problem in wheel marks in all traffic systems

Over 4 years Shallow till performed +15% over Zero till in wheel marks

Average tillage system effects over 4 seasons

Yield of Zero-till is 1.0t/ha (11%) less than mean of Deep and Shallow
Value of Zero till is £124/ha (11%) less than mean of Deep and Shallow
Yield and value of Shallow are 0.15t/ha and £20/ha greater than Deep

Assuming: Wheat £140/t, Barley £110/t, Oats £125/t

AHDB, November 2016

Estimated increase from wheel mark eradicator tines
Average traffic system effects over 4 seasons

Assuming: Wheat £140/t, Barley £110/t, Oats £125/t
AHDB, November 2016

Yield of CTF30% & CTF15% are 0.32t/ha and 0.61t/ha greater than RTF
Value of CTF30% & CTF15% are £41/ha and £77/ha greater than RTF
Yield and value of LGP are 0.1t/ha and £15/ha greater than RTF

Provisional classification for soil suitability for Direct Drilling (No-Till) of combine harvested crops.

After: Connell et al., 1978.
Redrawn by Farmers Weekly, 2015
Effect on Soil Organic Matter*

Wookey, 2016

* Loss on ignition – surface layer

P = 0.005

Traffic effect was not significant

Effect of Traffic and Tillage on Aggregate Stability*

Abel, 2016

CTF     LBP     RTF

Tillage
Zero    Shallow Deep

P = 0.02

Proportion of stable aggregates, %

Wet sieve test: 80mm diameter x 50mm deep sample; 0.6mm sieve size

Eijkelkamp, 2008
Effect of Tillage on Earthworm Population*

December P=0.004 and March P=<0.001

Total earthworm density (earthworms/0.35m²)

Zero 126 124
Shallow 104 95
Deep 71 73

Smith V.L., 2016

*Mustard solution

Benefits of worms and Good Husbandry Practices

Potential Benefits
- Improve aggregation and macro-porosity
- Stabilise soil organic matter
- Accelerate nutrient mineralisation
- May decrease negative impacts of some pests and pathogens (nematodes, fungi)

Practices to maintain worm population
- Reduced tillage or No-till
- Reduced use of pesticides
- Increase soil organic matter
- Diversify cropping
- Winter tillage is preferable to Spring

Crockford, 2017  Bertrand et al., 2015
Effect of earthworms

- Increased aggregate bulk density by between 0.07 and 0.11 g cm\(^{-3}\)  
  *Lavelle et al. 2004*
- Increased porosity by 21%  
  *Blanchart et al. 1997*
- 40t soil/ha/year = 0.4cm topsoil/year
- Reduce severity of soil borne fungal pathogens  
  *Stephens et al. 1994*
- Reduce damage by plant parasitic nematodes  
  *Blouin et al. 2005*
- Affect aphid development through nutrient content and enhance plant growth  
  *Scheu et al. 1999 and Eisenhauer and Scheu, 2008*

Impact on Nematode Population

- Controlled Traffic maintained the sensitive* nematodes more than the other traffic systems. *Larger with a slow reproduction rate.

- Zero tillage combined with High Pressure Traffic plots had significantly higher total abundance of Root-knot nematodes ** than the other treatment combinations. **(*Meloidogyne*)

- The disturbance-tolerant nematodes were most associated with Low Pressure traffic system. i.e., Disturbance is good, compaction is bad.

- Although CTF-Zero-till might appear to be the most conservative method, CTF-Deep tillage was the most beneficial for controlling the parasitic nematodes while maintaining a good population of microbivorous ones.

*Ahmed et al., in press. Soil Tillage Research*
Improving soil structure and crop yield by increasing soil organisms (earthworms).

Mineral fertiliser only
FYM since 2001 plus mineral N
FYM annually since 1852 plus mineral N

Barley yield (7.74, t ha$^{-1}$),
Topsoil Mechanical Impedance (4.2 MPa),
Earthworm fresh mass (32.2 g m$^{-2}$) and
SOC (35.3 g kg$^{-1}$).

Whitmore, 2016

The best additive is FYM
Jeffery, 2017

Benefits of a 7 year rotation
Including Limex 70, cover crops & turkey manure
Winter wheat yields for Salle Farms, Norfolk

Wheat and Spring Barley yield increased on average 0.10t/year
3 machines established all combinable crops - Carrier, Opus, Rapid
Anticipate further reductions in tillage depth (& power requirement).

Hovesen, Aspects of Applied Biology 134, 2017
Conclusions

• Minimising cultivation depth and disturbance can help improve soil health by raising soil organic matter content, worm and some nematode populations and soil structure, with little negative impact on crop yield.

• Pay attention to the effect of field traffic: reducing tyre inflation pressure and controlled traffic systems can help maintain soil structure, crop yield, soil fauna (and water infiltration rates).

• FYM is the best source of additional organic matter.

• To test for soil health – bury 2 pairs of cotton underpants for 8 weeks!

Acknowledgements

To the many students and staff of Harper Adams University that assisted in the data collection and analysis of the

Tillage x Traction study:

namely

David White, Keith Chaney, Ed Dicken, Matt Back, Keith Chaney
Emily Smith, Anthony Millington, Mohammed Ahmed,
Martin Abel, Vicky Smith, William Wookey, Tim Dicker

With a 6 year experiment well underway should a “Beneficials” study be contemplated?
Conservation Agriculture,
Experiences and Possibilities

Andrew Barr

Pulling out the arms race...
...before it’s too late!
AHDB (2014), *Encyclopaedia of pests and natural enemies in field crops*, Agriculture and Horticulture Development Board


---

**Figure 3.** Mean carabid activity-density on farms at different distance into crop in 2014

S. Springate & J. P. Haggar, Natural Resources Institute, University of Greenwich, UK
Companion Cropping Potential

![Graph showing % damaged plants by C. picitarsis](image)

CETIOM, France

Companion Cropping oilseed rape and vetch
- any effect on flea beetle or aphid numbers?
Results and observations from both Hinton and Marley suggest that there is scope for the use of companion crops, on a commercial scale, to protect emerging crops from the most damaging attacks by cabbage stem flea beetles.

Of the species investigated over a two year period, the most likely candidate for this role is white mustard.

NIAB
Wheat Companion Cropping

NIAB

IGER

Reading University

“The gardener or farmer also benefits in that they soon learn that any crop with 12 or better leaf Brix will not be bothered by insect pests.”

www.bionutrient.org
Housing Shortage?

Game and Wildlife Conservation Trust
### FLOWERS

<table>
<thead>
<tr>
<th>Common name</th>
<th>Family name</th>
<th>Latin binomial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fennel</td>
<td>PER NATURAL</td>
<td>Apiaceae Foeniculum vulgare</td>
</tr>
<tr>
<td>Tansy</td>
<td>PER NATIVE</td>
<td>Asteraceae Tanacetum vulgare</td>
</tr>
<tr>
<td>Yarrow</td>
<td>PER NATIVE</td>
<td>Asteraceae Achillea millefolium</td>
</tr>
<tr>
<td>Perennial cornflower</td>
<td>PER NonNATIVE</td>
<td>Asteraceae Centaurea montana</td>
</tr>
<tr>
<td>Oxeye daisy</td>
<td>PER NATIVE</td>
<td>Asteraceae Leucanthemum vulgare</td>
</tr>
<tr>
<td>Bird's foot trefoil</td>
<td>PER NATIVE</td>
<td>Fabaceae Lotus corniculatus</td>
</tr>
<tr>
<td>Red clover</td>
<td>PER NATIVE</td>
<td>Fabaceae Trifolium pratense</td>
</tr>
<tr>
<td>White clover</td>
<td>PER NATIVE</td>
<td>Fabaceae Trifolium repens</td>
</tr>
<tr>
<td>Tufted vetch</td>
<td>PER NATIVE</td>
<td>Fabaceae Vicia cracca</td>
</tr>
<tr>
<td>Cornflower</td>
<td>ANN NATURAL</td>
<td>Asteraceae Centaurea cyanus</td>
</tr>
<tr>
<td>Borage</td>
<td>ANN NonNATIVE</td>
<td>Boraginaceae Borago officinalis</td>
</tr>
<tr>
<td>Scorpion weed</td>
<td>ANN NonNATIVE</td>
<td>Boraginaceae Phacelia tanacetifolia</td>
</tr>
<tr>
<td>Common vetch</td>
<td>ANN NATURAL</td>
<td>Fabaceae Vicia sativa</td>
</tr>
<tr>
<td>Red dead nettle</td>
<td>ANN NATURAL</td>
<td>Lamiaceae Lamium purpureum</td>
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<td>Yellow rattle</td>
<td>ANN NATIVE</td>
<td>Orobanchaceae Rhinanthus minor</td>
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<tr>
<td>Buckwheat</td>
<td>ANN NonNATIVE</td>
<td>Polygonaceae Fagopyrum esculentum</td>
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<tr>
<td>Bishopsweed</td>
<td>ANN NATURAL</td>
<td>Apiaceae Ammi majus</td>
</tr>
<tr>
<td>Viper's bugloss</td>
<td>BI NATIVE</td>
<td>Boraginaceae Echium vulgare</td>
</tr>
<tr>
<td>Teasel</td>
<td>BI NATIVE</td>
<td>Dipsacaceae Dipsacus fullonum</td>
</tr>
</tbody>
</table>

#### Premium Budget

| 3 ha light soil | £5,800 | £5,500 |
| 2 ha heavy soil | £4,100 | £3,700 |

### GRASSES

<table>
<thead>
<tr>
<th>Common name</th>
<th>Family name</th>
<th>Latin binomial</th>
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</thead>
<tbody>
<tr>
<td>Common bent grass</td>
<td>Poaceae</td>
<td>Agrostis capillaris</td>
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<tr>
<td>Creasted dog's tail</td>
<td>Poaceae</td>
<td>Cynosurus cristatus</td>
</tr>
<tr>
<td>Cat's tail</td>
<td>Poaceae</td>
<td>Phleum bertolonii</td>
</tr>
</tbody>
</table>

#### Premium Budget

| 3 ha light soil | £2,500 | £2,500 |
| 2 ha heavy soil | £3,600 | £3,600 |

£ 2,667 to £ 3,850 per hectare
Feeding…. the plants, the soil, the predators, the pests?


Insecticides are used to manage pests, however, in some cases they also disrupt biological control, leading to unintended outbreaks of target or non-target pests (Geiger et al., 2010; Settle et al., 1996; Stern et al., 1959).

Meta-analysis reveals that seed-applied neonicotinoids and pyrethroids have similar negative effects on abundance of arthropod natural enemies

Margaret R. Douglas, John F. Tooker

Published December 7, 2016

No early fungicides –

Dwayne Beck, Dakota Lakes Research Centre
Dr Kristine Nicholls, Rodale Institute


SPRAYING LESS MEANS LESS SPRAYING?

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Anti-pesticide farm initiative passes the signature stage

Campaigners have handed in 114,420 signatures by Swiss citizens in favour of the “Clean Drinking Water and Healthy Food” initiative, which aims to cut direct subsidies to farmers who use pesticides or antibiotics.

A Plan...

**Osr**
- Architect
- Companion crop – beans / clover / cereal volunteers
- Trap crop – turnip rape / kale
- HSS and prepare to be flexible
- Do not spray for pollen beetle or seed weevil

**Wheat**
- Skyfall / Zyatt? / Deter?
- Clover understory / keep osr vols
- Not too early / apply compost
- No T0 fungicide
- No aphicide in autumn

**Beans**
- Spraying pointless?
- Or parasitic fungi?
- Plant into rye / oats cover crop mulch

**Backed up by**
- No-till
- Compost / manure
- Urea / UAN / foliar nutrients
- Countryside Stewardship
- LEAF Marque
- Field specific monitoring alerts
- Patience, flexibility
Effect of Different Intensities of Soil Cultivation on Extended Phenotypes and Predator Dynamics of *Tenuiphantes Tenuis*
Background

Childerley Farm, Cambridge
Examining impact of a direct drilling on soil and crop performance.

Conventional

Secondary Cultivation
Direct Drill

Conventional vs Direct Drill
Tenuphantes tenuis
Tenuphantes tenuis

Why T. tenuis

- 100% Carnivorous
- They capture more pests than they eat
- They can gorge and starve themselves
- They are not vectors of crop disease
Why Are Aphididae spp A Problem?

- Direct feeding of phloem depletes photo assimilates - monosaccharides
- They are vectors of disease
- Increasing resistance to insecticides
- *A. Pisum* – honeydew they produce encourages fungal growth
- Loss of yields = Loss of income

**Acyrthosiphon pisum**

---

**Why Are Aphididae spp A Problem?**

- S. avenae
- R. padi

---

- April 2017 – Scotland - First cereal aphids were caught in traps 3 weeks earlier than average. (SASA, 2017)
- December 2017 – Preston - Bird cherry - oat aphid numbers were unusually high. Sites are at or near their ten-year mean. Early emergence dates have presented a build-up of virus vector pressure. (AHDB, 2017)
Project Aims and Objectives

**Aims:**
To identify the potential biological control of *T. tenuis* of Aphididae spp. within different intensities of tillage in an arable crop.

**Objectives:**
- Observe behavioural changes in *T. tenuis*  
- Identify differences in extended phenotypes – Webs  
- Measure web location

- Quantify *T. tenuis* biological control - 
  Compare Aphididae spp. numbers in *T. tenuis* webs & *T. tenuis* gut with Aphididae spp. population

Methodology – In The field
Methodology – In The field

Methodology – In The field
Methodology – In The field
Methodology – In The field
April – Spring Barley

Mean Total Vertical Crop Stubble From Random Plots In Different Areas of Soil Cultivation

P-Value - 0.001

Results from the field

Mean Total Thread Length (mm) From Random Plots In Different Areas of Soil Cultivation

P-Value - 0.001
April – Spring Barley

Results from the field

Total Vertical Crop Stubble = 42.09 + 0.8366 Sheet Thread Length (mm)

P-Value - 0.002

P-Value - 0.023
Results from the field

April – Spring Barley

Anchor Point Height (cm) = 7.331 + 0.03231 Total Support Thread Length (mm)

Anchor Point Height (cm) = 8.973 + 0.04372 Total Sheet Thread Length (mm)

P-Value - 0.020

P-Value - 0.033
Results from the field

July – Winter Wheat

- Total *T. tenuis* - 0.388
  - Male - 0.317
  - Female - 0.272
- Total Web Area - 0.407
- Planting Density - 0.358
- Aphid Total - 0.135

PCA – Loading Plot
Field Data June 2017

- Total *T. tenuis* - 0.388
  - Male - 0.317
  - Female - 0.272
- Total Web Area - 0.407
- Planting Density - 0.358
- Aphid Total - 0.135
Discussions from the field

• Significant Positive Regression – Total Stubble Vs Total Thread Length
Stubble may provide a sturdier base for attachment than crop. The highly mobile *T. tenuis* is inclined to construct webs at a fast pace.

• Significant Positive Regression – Anchor Height Vs Total Thread Length
*T. tenuis* have preference to anchor their webs high in a habitat. A high web will intercept an increased number of prey.

• PCA- First Component = Total *T. tenuis*, Planting Density – High Association
  Male more influence than females
Two Component = Aphid Total – Lower Association
Less reliance on stubble. Higher heterogeneity with crop.
Males ready to mate – create sperm induction webs.

Are *T. tenuis* numbers associated with abundance of Aphididea spp?

Results from the field - Hedges

**November – Winter Wheat**

![Graphs showing mean data area (mm²) and mean thread length (mm) from random plots in hedges opposite different areas of soil cultivation.]

P - Value – 0.001 Kruskal Wallis

P - Value – 0.001
Results from the field - Hedges

**November – Winter Wheat**

- **General Linear Model**
- Anchor Height against
  - Soil Cultivation, Material,
  - Distance from Field Margin

- **R-Sq = 81.36% - Model fits the data**
- **Material**
  - Branch $P$ – Value 0.001 Grass $P$ – Value 0.003
- **Soil Cultivation**
  - Direct Drill Cultivation $P$ – Value 0.026
  - Statistically significant association
    - between response variable and the term

**December – Winter Wheat**

- No Significance Difference –
  - Egg Sac Dimensions & Anchor Point Height
- Egg Sacs only found in Direct Drill hedges.
Discussions from the field - Hedges

- Significantly higher Mean Web Area and Mean Thread Length - Direct Drill Hedge
- Egg Sacs only in Direct Drill Hedge
  T. tenuis balloon to nearest habitat. Suggests more T. tenuis occupied Direct Drill Crop.

- General Fit Model – Material and Direct Drill Significant
  Do the hedges of Direct Drill that have been sampled have a higher vegetation density?

Stubble on Conventional

Direct Drill

Direct Drill Managed

Conventional
Results from Stubble on Conventional

- No significant difference to anchor points on outside stubble or inside stubble.

Discussion Stubble on Conventional

- Significance Difference in Total Thread Length & Total Web Area – Greatest in Direct Drill

Again stubble huge importance. How can the stubble be left after conventional tillage?
Laboratory Experiments

Mesocosm One – Growth of Barley in The Glass House

Why?
Remove External Variables
• Wind / Rain
• Shelter

Allow for closer examination
• Web Design

Bamboo Sticks
For Support

Polythene Sheet
Covering 60µm Thick

Insect Mesh

Planet Barley
Dressed In Raxil® Star

Stubble
Corresponding To Field Site

Hydroponic Clay
Balls

Straw
Corresponding To Field Site

Top Soil Taken
From Cambridge

Black Thin Weed
Sheet
Methodology – Mesocosm One

Imitating Intensity of Soil Cultivation

Conventional  Direct Drill Managed  Direct Drill

Results from Mesocosm One

Mean Anchor Point Height (cm) of Different Soil Tillage Intensities in Mesocosm One

P-Value - 0.017

Interval Plot of Mean Anchor Point Height (cm) vs Treatment, 5

95% CI for the Mean
Results from Mesocosm One

**Mean Total Thread Length (mm) vs Treatment**

- **Interval Plot of Mean Total Thread Length (mm) vs Treatment**
- **95% CI for the Mean**

**PCA**

**Loading Plot of Abdomen Length, Mass**
- Anchor Height 0.480

**P-Value - 0.012**
Discussion Mesocosm One

- **Significance Difference in Total Thread Length**
  Direct drill has shown to support more *T. tenuis* activity due to a more complex environment.

- **Significance Difference in Anchor Height**
  High attachment points in conventional may be due to less stubble.

- **PCA shows Anchor Height and Thread Length are closely associated.**

  The decision where a thread is anchored is key for thread spinning for web creation.

---

DNA Barcoding for Gut Analysis

**Measuring Predator / Prey Relationships**
Further work

Field Work
• Carry on Field Work until December 2018

Laboratory Work
• Specific Aphid DNA Primers - Validate
• Aphid DNA analysis in T. tenuis gut and on webs
• Mesocosms to see how soil tillage intensity may effect:
   Renewal of webs
   Occurrence of 2-layered sheet web

Acknowledgements

• Thank you to my Spider Supervisors -
  • Dr. Richard Collins
  • Dr. Jaime Martin
  • Dr. Kevin Butt
Any Questions

Email me at acampbell@myerscough.ac.uk
I will be happy to answer!!!

SPONSORS
We are very grateful to the following companies who have sponsored the BCPC Pests & Beneficials Review 2018

Refreshments
11:15 – 11:30
Successful application of biocontrols in outdoor crops
Michelle Fountain, Chantelle Jay, Jean Fitzgerald, Jerry Cross, Csaba Nagy, Alvaro Delgado, Adrian Harris, Bethan Shaw, Maddie Cannon

Introduction

• Biological control
  • Parasitoids, predators and pathogens

• Conservation biological control
  (Kenneth W. McGravy)
  • practices - maintain and enhance reproduction, survival and efficacy of natural enemies
  • avoidance of harmful practices
  • knowledge of biology and requirements needed

• Inductive (augmentation) - large population of natural enemies administered for quick pest control – PREVENTATIVE or CURATIVE

• Classical (importation) - where a natural enemy of a pest is introduced into a new area
• Conservation biological control

Pear sucker damage

A man-made pest!

Pesticide resistant!
Pear sucker out of control

Plant Science into Practice
Modern Italian alder windbreaks

Devoid of biological control

Plant Science into Practice

Sources of anthocorids

Stinging nettle
(Urtica dioica)

Goat and grey willow (Salix)

Hawthorn (Crataegus)

Hazel (Corylus avenana)
Common earwig
*(Forficula auricularia)*

Lab tests of sub-lethal effects on nymphs

- Combined autumn and spring earwig mortality and delayed egg laying = third fewer eggs the following year with some insecticides

*Plant Science into Practice*
Field applications

- Single applications of some insecticides early or late in the growing season had no discernible effect on earwig numbers in the field.
- However earwig nymphs may be more sensitive to products from May onwards when they move into the trees.

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>NIAB EMR</th>
<th>Other researchers</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>abamectin</td>
<td>Some long-term mortality</td>
<td>Harmful</td>
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<tr>
<td>acetamiprid</td>
<td>Minimal effects</td>
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<tr>
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<td>Safe</td>
<td>-</td>
<td>9</td>
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<tr>
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<td>Safe to adults</td>
<td>16.10</td>
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<td>11.1</td>
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<td>cypermethrin</td>
<td>-</td>
<td>Harmful (nymphs), knockdown</td>
<td>14.7,8</td>
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<td>diflubenzuron</td>
<td>-</td>
<td>Harmful</td>
<td>6.11</td>
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<td>Safe, harmful</td>
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<td>methoxyfenozide</td>
<td>Harmful to nymphs (growth)</td>
<td>Safe to adults</td>
<td>6.9</td>
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<tr>
<td>pirimicarb</td>
<td>Safe</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>potassium bicarbonate</td>
<td>-</td>
<td>Safe</td>
<td>12</td>
</tr>
<tr>
<td>spinosad</td>
<td>Harmful, knockdown</td>
<td>Harmful</td>
<td>13.8,8,11</td>
</tr>
<tr>
<td>spinosadifen</td>
<td>Long-term mortality, delayed laying</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>thiacloprid</td>
<td>Harmful, some long-term mortality</td>
<td>Harmful</td>
<td>13.8,11</td>
</tr>
</tbody>
</table>

• Inductive (augmentation) biological control
Neoseiulus cucumeris in strawberry

- For control of Western Flower Thrips
- Eggs and first instars
- Long use
- Fortnightly application
- Mechanisation
- Used in combination with other biocontrols including Phytoseiulus persimilis for spider mite control and parasitoids for aphid control

Other lifecycle stages of Thrips

Machrocheles robustulus and/or the nematode Steinernema feltiae

Hypoaspis miles (Stratiolaelaps scimitus) and/or the nematode Steinernema feltiae
Can this work in cherry?

- *Amblyseius andersoni*
- Growing cherries under protection
- Two spotted spider mite (*Tetranychus urticae*)
- European fruit tree red spider mite (*Panonychus ulmi*)
- one Gemini sachet per tree
- one Gemini sachet per 5 trees

More predatory *A. andersoni* where sachets applied

Mean number per 60 leaves

<table>
<thead>
<tr>
<th></th>
<th>High</th>
<th>Low</th>
<th>Untreated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predator eggs</td>
<td>2 b</td>
<td>2 b</td>
<td>2 a</td>
</tr>
<tr>
<td><em>A. andersoni</em></td>
<td>10 b</td>
<td>10 b</td>
<td>10 b</td>
</tr>
</tbody>
</table>
**Fly in the ointment**

- *Drosophila suzukii* – Spotted Wing Drosophila
  - Invasive from Asia
  - Lays eggs in ripening fruit
  - Causing collapse of fruit before harvested
  - Identify native parasitoids of *D. suzukii*
  - Over 280 SWD sentinel traps
  - Range of sites – crops and wild areas
### Species of parasitoid discovered in England

<table>
<thead>
<tr>
<th>Family, Species</th>
<th>Habits</th>
<th>Individuals</th>
<th>Traps</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pteromalidae</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pachicrepoydeus</em></td>
<td>Woodland, Brambles, Elderberry edge,</td>
<td>1100</td>
<td>31</td>
</tr>
<tr>
<td><em>vindemmiae</em></td>
<td>Farmyard, Hedgerow, Raspberry and Strawberry edges, Wild cherry orchard and Vineyard</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Spalangia</em></td>
<td>Woodland, Hedgerow, Raspberry and strawberry edges, Wild cherry orchard</td>
<td>219</td>
<td>14</td>
</tr>
<tr>
<td><em>erythromera</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Figitidae</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Leptopilina</em></td>
<td>Woodland</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td><em>heterotoma</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Braconidae</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Asobara tabida</em></td>
<td>Woodland</td>
<td>9</td>
<td>2</td>
</tr>
</tbody>
</table>

Conservation Biocontrol or Classical Biocontrol (Gnapsis sp. from Asia)

---

Many thanks for listening

---

UK fruit growers
Cost-benefits of thresholds

Mark Ramsden
Crop Protection

What is a thresholds?
The role of beneficials
Farm focused research
Economic thresholds

- Pollen beetle
- Virus vectors (e.g. aphids)
- Cabbage seed weevil

More than 0.5/plant in northern Britain
1/plant elsewhere

Ramsden et al. (2017) Crop Protection 96, 30-43

A little bit of crop physiology...

SOURCE

SINK
Summary example – Pollen beetle

Denser crops produce fewer excess flowers per plant
Summary example – Pollen beetle

1 adult pollen beetle eats about 9 buds

Excess pods can be lost with no impact on yield
Is action needed?

How to avoid exceeding thresholds
What is a thresholds?

The role of beneficials

How to avoid exceeding thresholds
How to avoid exceeding thresholds

How to avoid exceeding thresholds
How to avoid exceeding thresholds

Number of pests

Time

Increase threshold
Reduce pests

Reduce pests - role of beneficials

Population growing
Population shrinking

Number of pests
Time

Number of Natural enemies
Do natural enemies make a difference?

Chaplin-Kramer et al. (2013)
Agricultural, Ecosystem and Environment, 181, 203-212

Ramsden et al. (2016)
Agricultural and Forest Entomology

Reduce pests - role of beneficials

Population lag
Scale of interactions

Number of pests

Time
Reduce pests - role of beneficials

Population lag

Scale of interactions

Reduce pests - role of beneficials

Population lag

Scale of interactions

Reduce pests - role of beneficials

Population lag

Scale of interactions

Reduce pests - role of beneficials

Population lag

Scale of interactions
Resource provision needs to be targeted, and takes place at different scales to crop management.

IPM solutions may need to be implemented at multiple scales, across several crops, over several years.

Success will be dependent on understanding the ecology of the pest.
What is a threshold?

The role of beneficials

Farm focused research

Obstacles to implementing thresholds

Calendar/insurance based insecticide application
- Obvious results
- Forgiving application
- Established methods
- Cheap
- Quick

Threshold based applications
- Relative results
- Difficult to get right
- Complex systems
- Investment needed
- Slow

Farm Focused Research
- Pest remains in crop
- IPM solutions may not work
- Numerous spatially varying techniques
- Establishing field margins
- Benefits accumulate over years

Obvious results
- All insects gone
- Sub-optimal application still works
- Fits with existing systems
- Relatively low short-term costs
- Can have immediate effect
Farm focused research

Thresholds provide a mechanism for testing ideas

What is a thresholds?

The role of beneficials

Farm focused research
Credits from past research

Chemicals Regulation Directorate

Pete Berry
Steve Ellis
Sarah Kendall
Kate Storer
Sacha White

Cost-benefits of thresholds

Mark Ramsden
Crop Protection

Questions...
Building Confidence in Beneficials: Conservation BioControl in Oilseed rape

Sam Cook
Biointeractions & Crop Protection Department

Insects love oilseed rape!
Oilseed rape is important for farmland biodiversity

Oilseed rape supports a wide variety of invertebrates:

Surveys in UK using a range of techniques...

...collected 151 species + c. 40 additional groups identifiable to genus or higher taxonomic rank

Skerrin & Cook in prep

Oilseed rape is important for farmland biodiversity

Oilseed rape crops support populations of bees, butterflies & other pollinators, natural enemies of crop pests, detritivores & invertebrates used as food resources for farmland birds

Skerrin & Cook in prep
Oilseed rape is important for farmland biodiversity

Can we manage the crop to boost biodiversity... ...and make it work for us?

Talk outline:
- What is Conservation Biocontrol?
- What are the natural enemies of oilseed rape pests in UK?
- What’s their impact on crop pests?
- How can we manage crops to protect populations of natural enemies and encourage pest regulation?
What is Conservation BioControl (CBC)?

Biological control is a method of controlling pests using other organisms (natural enemies)

- Predation
- Parasitism
- Pathogens

Conservation Biological Control = Use of agronomy & habitat management methods to conserve the natural enemies of crop pests in the agri-environment to provide pest regulation...as opposed to:

- Classical biological control = introducing natural enemies from a pest's native range into a new area where native natural enemies do not provide sufficient control

- Augmentation biological control:
  - Incolulative biological control = periodically releasing natural enemies to re-establish a balance
  - Inundative biological control = massive production and release of natural enemies to control the pest quickly (e.g. bio-insecticides)
What are the pests in OSR – and their natural enemies?

Brassica- specialist pests
Larvae inhabit on/in plants
Pupate plants /in soil

What are the natural enemies of OSR pests?

Generalists prey on several groups: canopy active
Ladybirds: prey on aphids and small larvae e.g. pollen beetle from flowers
Maybe lacewings? Maybe hoverfly larvae? Ballooning / money (Linyphiid) spiders?
What are the natural enemies of OSR pests?

Generalists: ground-active (some species may climb plants)

Spiders:
Lyconid wolf spiders e.g. Pardosa agrestis
Tetragnathidae (long jawed spiders)

Staphylinid (rove) beetles

Carabid (ground) beetles 42 species common in OSR fields; some with very high density
Spatial association between:
- CSFB eggs and larvae and 2 spp (Trechus quadristriatus & Pterostichus madidus) (Warner et al., 2003)
- Pollen beetle larvae and 6 spp (Amara similato, Anchomenus dorsalis, Nebria brevicollis, Harpalus affinis, H. rufipes, Poecilus cupreus) (Felsman & Buchs 2006; Warner et al 2008)

What are the natural enemies of OSR pests?

Specialists: parasitic wasps (parasitoids) 80 spp in total

The pest | The parasitoid
---|---
Psylliodes chryscehalda | Tersilochus mirogastra
Meligethes aeneus | Phenax interstitialis
Tersilochus heterocerus
What are the natural enemies of OSR pests?

Specialists - attack 1 or a few related species: parasitic wasps (parasitoids)

The pest

The parasitoid

Trichomalus perfectus

Platygaster subuliformis

Omphale clypealis

Effects of natural enemies on OSR pests

- Biocontrol potential of several spider and carabid spp. confirmed by gut analyses
- Biocontrol potential of carabids and parasitoids confirmed by analysis of spatio-temporal distributions

Warner et al.
Effects of natural enemies on OSR pests

- Predators – data on effects on pests in OSR are scarce; c. 20% of total pollen beetle mortality (Büchi, 2002; reviewed by Bücht 2003).
- Parasitoids – parasitism rates for pollen beetle can reach c. 80% in untreated crops
- ‘Parasitoids more important than predators for biocontrol’ (Nilsson & Andreasson 1987; Hokkanen 1988)
- Key parasitoids only attack larvae (no good for pest management in the current crop!
- To improve confidence in beneficials for biocontrol: more research needed into quantifying control effects and relating these to yield.

Conservation biocontrol: Conservation via agronomy

Skellern & Cook (2018) Arthropod-Plant Interactions
Temporal succession of parasitoid emergence

-conservation via agronomy: Insecticides

Spray ONLY when necessary!

Spatial targeting of insecticides in pest hot-spot areas will help to conserve natural enemies

-conservation via agronomy: Insecticides
Conservation via agronomy: Tillage

- Most parasitoids of OSR pests overwinter as cocoons in the soil after dropping from OSR plants
- Ploughing in preparation for wheat crop buries the cocoons reducing emergence
- Minimum/zero-til systems significantly improve parasitoid survival (Nilsson et al. 2003, 2010)
- ... and also benefit populations of spiders and carabids

Conservation via habitat management: Field margins

*Delivering conservation biocontrol via Field margins*

- Areas of uncropped land, between the arable crop and the boundary (e.g. hedge)
- Actively managed; sown to annual, but usually biannual or perennial plants; 3, 6 or 12m wide
- Introduced in several countries as part of Agri-environment schemes (EU CAP)

Commercial mixtures for birds, bees/butterflies but none for biocontrol!

- Plant composition needs to be optimised to maximise biocontrol potential
Conservation via habitat management: field margins

- Uncultivated field margins can act as refuges for tillage-susceptible parasitoid populations to thrive
- Flowering field margins can improve pollen beetle parasitism on neighbouring crops (by provision of pollen and nectar resources) (Thies & Tscharntke (1999); Buchi (2002))
- Brassicas needed to build-up populations of brassica-specialist parasitoids (!)
  - Insect samples & plant composition was monitored from 16 margins sown to 4 different types of semi-natural habitat: (1) wild bird cover (2) florally-enriched grassland (3) insect rich cover (4) natural regeneration
  - 50 parasitoids of OSR pests were identified; only 3 were in margins containing no brassicas

What Brassica(s) best support parasitoids of OSR pests?
- 14 Brassica types screened

Brassica napus subsp. Biennis Forage rape best ‘all-rounder’ - Good for parasitoids of:
- Pollen beetle
- Seed weevil
- Pod midge
Conservation via habitat management: field margins

Do brassica margins improve biocontrol in crops?

**Brassica Margins:** Increased biodiversity and biocontrol agents particularly brassica specialists

**Crop:**

- **Wheat:** No significant differences between margin treatments
- **OSR:** More spiders and several carabid spp in OSR crops next to brassica margins than grass margins
Summary

• OSR crop support a wide variety of invertebrates, including predators and parasitoids of pests
• Biocontrol agents of OSR pests well known but more research needed on quantitative effects on pest control and yield
• Agronomical methods (reduced sprays & tillage) and habitat management methods (field margins) can increase populations of beneficials
• Field margins containing brassicas increased beneficials (particularly specialists) at field edges
• Abundance tends to decrease with distance into the field
• Little evidence of significant biocontrol effects in the crop
• Challenge for future:
  - move biocontrol agents into the open field
  - show positive effects on yield

Acknowledgements

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Lucy Nevard
Andrew Moss
Jason Baverstock
Martin Torrance

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Dr Judith Pell (UK Pest Consulting)
DR Gabor Kiss (AUK, Denmark)

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under the grant agreement n°244604/PURE.
We are very grateful to the following companies who have sponsored the BCPC Pests & Beneficials Review 2018

Field Margins (and beyond...)

David George, Stockbridge Technology Centre

Background
Why bother & will any seed mix do?

Case Study
Multi-functional field margins
“...and beyond”
Whole farm habitat management
Why bother? Natural checks on pests can be a highly effective alternative to chemistry…

This time next year in a world with no constraints on pest populations*…

The 200 000 million descendants of 1 pair of houseflies cover the earth to a depth of 15km

The descendants of 1 aphid mother – at 250 million tonnes – circle the equator a million times

The descendants of 1 pair of cabbage whites - with wings closed - cover Australia with a tower rising into the stratosphere faster than the speed of light

*Assumes max. fecundity and zero mortality…fortunately unrealistic!

These checks have inherent monetary value, and promoting ecosystem services is likely to result in future policy-driven payments

We hold our natural environment in trust for the next generation. By implementing the measures in this ambitious plan, ours can become the first generation to leave that environment in a better state than we found it and pass on to the next generation a natural environment protected and enhanced for the future.

The Prime Minister
But, not all seed mixes deliver for biocontrol

Considered seed selection is key


But, not all seed mixes deliver for biocontrol

Considered seed selection is key

Yarrow, tennel

Coriander, sweet alyssum

Oxeye daisy
Considered seed selection is key

Yarrow, fennel

Oxeye daisy

Coriander, sweet alyssum

Visitation by beneficial insects

Blue = observed in flower margins; Green = observed in grassy margins. Sum of 6 visits per year, n = 4.
Aphids in cabbage planted with a margin

- Parasitism rates increased more rapidly near flower margins
- Reduced aphid loads near to flower margins on some dates

Crop yield across crops planted with margins

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Carrots</th>
<th>Cereals</th>
<th>Peas</th>
<th>Cabbages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>No difference</td>
<td>No difference</td>
<td>Could not be analysed: poor crop</td>
<td>No difference</td>
</tr>
<tr>
<td>2011</td>
<td>No difference</td>
<td></td>
<td>Yield increased near margin by 22.5%_max</td>
<td>Yield increased near margin by 41.1%_max</td>
</tr>
<tr>
<td>2012</td>
<td>No difference</td>
<td></td>
<td>Yield increased near margin and field centre by 74.2%_max</td>
<td>Yield increased near margin by 15.8%_max</td>
</tr>
<tr>
<td>2013</td>
<td>Yield decreased near margin by 25.4%_max</td>
<td>No difference</td>
<td>No difference</td>
<td>No difference</td>
</tr>
</tbody>
</table>

Biological systems are inherently variable and benefits of even the very best seed mixes may not be seen year-on-year.
<table>
<thead>
<tr>
<th>Year</th>
<th>Carrots</th>
<th>Cereals</th>
<th>Peas</th>
<th>Cabbages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>No difference</td>
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<tr>
<td>2011</td>
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<td>Yield increased near margin by 15.8% max</td>
</tr>
<tr>
<td>2012</td>
<td>No difference</td>
<td>No difference</td>
<td>Yield higher near margin and field centre by 74.2% max</td>
<td>Yield increased near margin by 29.9% max</td>
</tr>
<tr>
<td>2013</td>
<td>Yield decreased near margin by 25.4% max</td>
<td>No difference</td>
<td>No difference</td>
<td>No difference</td>
</tr>
</tbody>
</table>

Biological systems are inherently variable and benefits of even the very best seed mixes may not be seen year-on-year. Would margins + trap crops be a viable option?
Margins + in-crop measures

Increasing in-crop biodiversity could be especially beneficial in meeting ‘new CAP’ requirements – ‘Polycultural Potential’

<table>
<thead>
<tr>
<th>Pest, disease, weed control</th>
<th>Improved cover and reduced erosion/runoff</th>
<th>Improved OM input and water retention</th>
<th>Increased floral resource</th>
<th>N fixation and carbon storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced pesticide</td>
<td>More sustainable / robust soils</td>
<td>Better drought tolerance</td>
<td>More bees</td>
<td>Reduced env impact</td>
</tr>
</tbody>
</table>

Reduced yield
But could polyculture fit with high yielding conventional UK farming models?

How do we drill into this? How do we manage this?

High tech machinery with sub-inch accuracy
**Preliminary 2016 data encouraging**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Dry ear (from 10 g sub sample) weight (g)</th>
<th>Fresh ear (from 50 x 50 cm quadrat sample) weight (g)</th>
<th>Dry straw (from 10 g sub sample) weight (g)</th>
<th>Fresh straw (from 50 x 50 cm quadrat sample) weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional bare soil</td>
<td>45.29 ± 1.51</td>
<td>149.39 ± 40.82</td>
<td>9.26 ± 0.63</td>
<td>96.60 ± 35.16</td>
</tr>
<tr>
<td>Direct-drill living mulch</td>
<td>45.55 ± 0.48</td>
<td>139.42 ± 24.07</td>
<td>8.83 ± 0.41</td>
<td>85.28 ± 24.54</td>
</tr>
<tr>
<td>Strip-till living mulch</td>
<td>45.66 ± 0.93</td>
<td>173.39 ± 42.51</td>
<td>10.57 ± 2.48</td>
<td>100.90 ± 22.88</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Nitrogen content (% of the total weight)</th>
<th>Moisture (% of the total weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional bare soil</td>
<td>1.94 ± 0.08</td>
<td>15.50 ± 0.15</td>
</tr>
<tr>
<td>Direct-drill living mulch</td>
<td>1.88 ± 0.04</td>
<td>15.68 ± 0.15</td>
</tr>
<tr>
<td>Strip-till living mulch</td>
<td>1.91 ± 0.03</td>
<td>15.53 ± 0.06</td>
</tr>
</tbody>
</table>

**The present for many; past for some…**
The future?

- Pollination
- Pest control
- Nutrient efficiency
- Fuel/labour costs
- EFA/AES points
- £ pest control

http://www.stockbridgetechnology.co.uk/
+44(0)1757 268275
Linking Biodiversity & Profitable Farming: Introducing Hillesden and ASSIST

Richard Pywell
rfp@ceh.ac.uk

Structure

1. Designing & testing habitat for ‘beneficials’
2. Benefits to the farm business: Hillesden
3. Where next? The ASSIST programme
1) Designing Habitat for ‘Beneficials’

- Six commercial farms
- Six new AES prescriptions tested
- Conventional crop control
- 5 years monitoring
Multiple Benefits from Wildflower Margins

GHG capture
Pollination
Soil carbon by %LOI

Nutrient cycling
Pest control

Crop to the edge
Grass margin £70 ha⁻¹
Wildflower margin £280 ha⁻¹

Enhancing Natural Pest Control

Image credit: Matt Cole Macro Photography
Natural pest control

Surface active predators

Sward active/flying predators

Testing this in the under field conditions

- Natural pest control reduced the survival of aphid colonies
- The best pest control is next to flower rich field margins
- Spill-over into the crop remains a problem

Colony survival when open to all predators
Benefits to Pollinator Populations

Pollinator methods

Field surveys
- Sampled DNA from live queens and workers in every habitat patch across the 20km$^2$ landscape (ca. 3,200 bees)

Molecular genetics
- Genotyped samples then grouped individuals into nests and ‘families’

Landscape modelling
- Relate bumblebee data to detailed maps of the landscape obtained using field surveys and high-resolution aerial remote sensing data
Effects of habitat on bee foraging distance

The more flowers in the landscape, the less distance bumblebees forage for resources.

Redhead et al (2016) Ecological Applications

Effects of habitat on between-year survival

First evidence that habitat creation benefits bumblebee populations.

“Family lineage survival”

Cover of semi-natural vegetation within 1000m of the colony.

LETTER

Bumblebee family lineage survival is enhanced in high-quality landscapes.
2) Benefits to the Farm Business: Hillesden Farm Platform

- Commercial 1000ha lowland arable farm
- Heavy soil growing autumn-sown crops (WW / OSR & beans)
- FIFTEEN 50-60ha ‘farmlets’ = three treatments replicated FIVE times:
  - Cross Compliance (0% land removed)
  - Typical Entry Level AES (3% land removed for two wildlife habitats)
  - Entry Level Extra AES (8% land removed for six wildlife habitats)
- Habitat creation in awkward/low yielding areas (mostly margins/corners)
- Test bed for AES policy
Abundance of ‘Beneficials’

Effects on yield (6yrs): all crops

Effects on yield: Beans
Crop yield performance

The Theory: Ecological intensification

‘Optimal management of ecological processes and beneficial biodiversity to improve agricultural productivity, efficiency and resilience to future shocks’

Integrated within precision farming systems
3) What next?
• 5+ year £11M research programme
• Uniting expertise from NERC and BBSRC institutes, with support from the farming industry
• Develop innovative farming systems to increase efficiency of food production & resilience to future shocks
• Reduce the environmental footprint of agriculture

WP1 LIMITATIONS ON CROP PRODUCTIVITY

• Understanding limitations on crop yield
• Overcoming the yield gap
• Influence of bio-physical factors on yield resilience
• Predicting future crop yields

Data collection & analysis
Detailed infield measures
National surveys

➢ Long-term yield data
➢ Crop input data
➢ Soil data
WP2 Environmental impacts of future agriculture

• Predict impacts of current and future agriculture
• Inform future mitigation strategies
  ➤ Scenarios of intensification / extensification
  ➤ New process models of water quality and GHG emissions
  ➤ Predict resilience of beneficial biodiversity
  ➤ Complement national monitoring

WP3 Sustainable solutions

• Network of 18 commercial study farms
• Real world test of ecological intensification with best agri-tech farming
• Co-designed by industry
• Enhance soil function, pollination & pest control
• Opportunity for technology transfer/complementary research
• Bringing the ‘Beneficials’ into the field
• Infield strips of bespoke flower habitat for natural enemies & pollinators

WP4 Synthesis: optimisation of future landscapes

• Develop modelling framework to optimise farm management for multiple objectives (production, ecosystem services, biodiversity):
  ➢ Where to intensify/extensify production (WP1),
  ➢ Impacts of changed agricultural management on natural capital and biodiversity (WP2), and
  ➢ Application of intervention measures to mitigate/enhance these effects (WP3)
  ➢ Build resilient future agro-ecosystems
Thank you
Richard Pywell (rfp@ceh.ac.uk)
www.ceh.ac.uk/assist
Essex ‘desert’ changes tack to beat the drought

Dry conditions have created a virtual desert in one part of Essex. Edward Long finds out how one combineable crops farmer is responding.

Changes in the seasonal weather pattern and a severe lack of rain are forcing an Essex farm to change its strategy and tailor cropping to the new dry conditions.

Between 1964 and 1982 the average annual rainfall measured at an official weather station at Lee Wick Farm, St Osyth, part of Wigboro Wick Farm, was just 518mm (20.5in). That was low enough for it to gain a listing in The Guinness Book of Records as the driest farm in the country.

“But since then we have had even less rainfall,” says Guy Smith, who, with brother Philip and father Andrew, farms 530ha (1360 acres) of combineable crops and potatoes on the coast near Clacton.

“Last year we recorded just 12.8in, the lowest rainfall total for over 40 years and far worse than the 1976 drought, when the ‘Big dry’...
26/02/2018

Price volatility

NFUnited
There’s strength in members.
Optimise inputs

“Produce more impact less”

Reduce impact

Improve productivity

Greater public goods

**Productivity**

R&D, skills & training, KE, market intelligence, business development and forecasting, POs

- eg. Innovation delivering resource efficiency
- eg. Grants, allowances and loans

**Environment**

- eg. Direct payments

**Volatility**

- Insurance schemes, financial instruments, fiscal measures including taxation

NFUnited
There’s strength in members.

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ELS/ HLS Expirees Compared to CS Uptake

![Graph showing ELS/HLS expirees compared to CS uptake over years.](image-url)
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