FEEDING THE WORLD CONFERENCE

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Are GM crops fit for purpose? If not, then what?

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GM Crops and Biodiversity – is this solely a GM issue?

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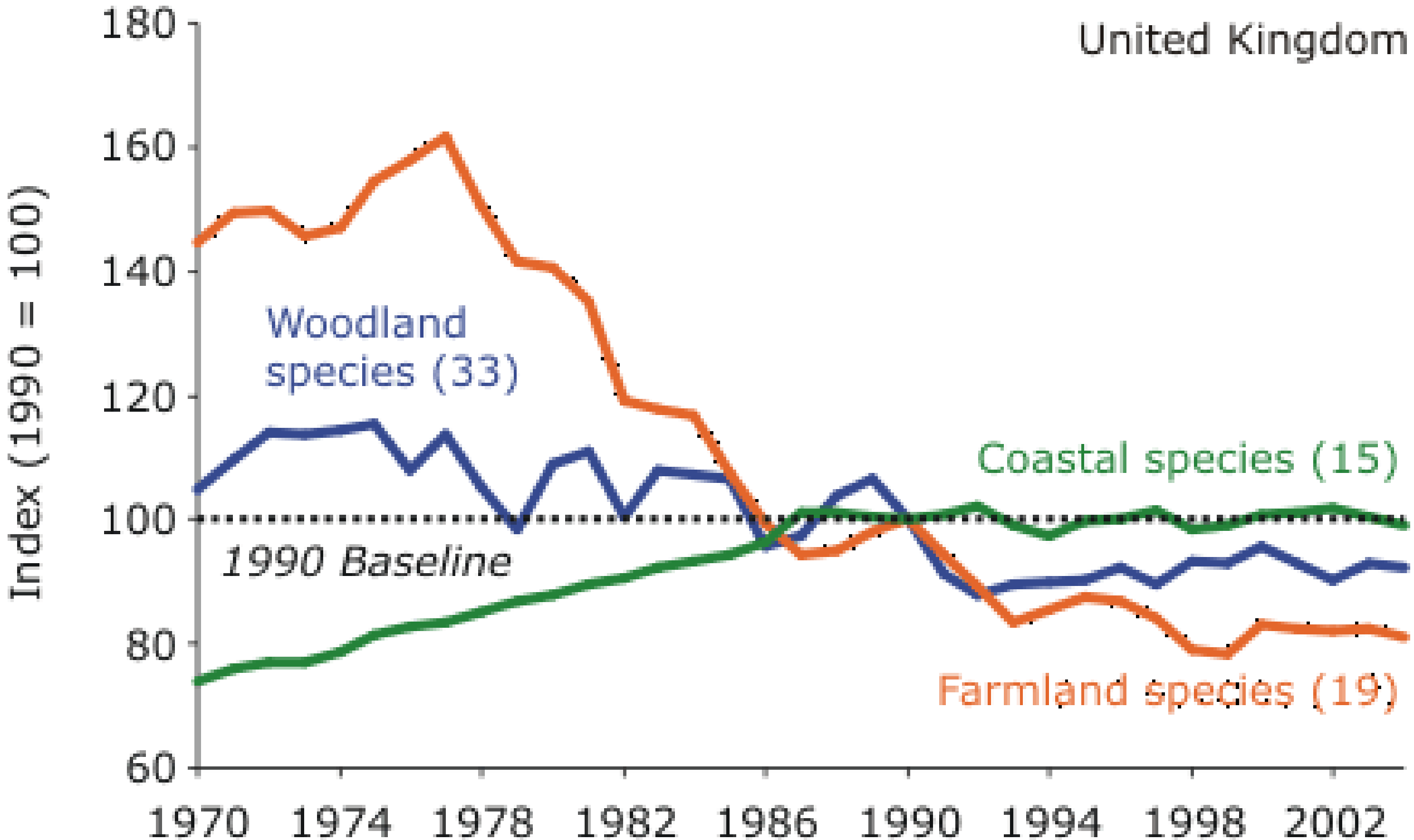
Why does farmland biodiversity matter?

- A high proportion of our natural biodiversity lives and breeds on farmland. We have international obligations to conserve it
- Farmland biodiversity acts as a warning system before humans are affected by agrochemicals etc
- For many people farmland biodiversity is their day to day contact with nature – it matters!
- Farmland ecosystems provide natural predators and parasites that deal with pests and diseases, some of which are also part of the ecosystem.
- Soil biodiversity is the key to soil health – huge arable areas now have impoverished and degraded soils

Agriculture in the North

- In Europe and some parts of the Americas new cropping systems have been used with no prior assessment of biodiversity impacts – autumn sowing, powerful herbicide regimes, maize, soybeans, reseeding and silaging. Huge increases in food productivity.
- These systems have driven farmland biodiversity almost to extinction within many crops, especially cereals – almost no weeds, no seed return, no fallow, very little humus return. Biodiversity just hangs on in hedgerows, in beet and vegetable fields and in oilseed rape crops
- This has all been done with *conventional* crop varieties, *not* GM
- The paradigm has been to adapt the environment to the crop, not the crop to the environment



Note: Figures in brackets give the number of species included in each category

Source: Defra, RSPB, BTO

Agriculture in the South

- **In many parts of Africa two out of three crops fail because of drought, salinity, pests and diseases. Yields are often 20% of yields for same crop in richer areas**
- **Irrigation water is scarce.**
- **In some countries half the crop is lost during food storage and distribution – bacteria and fungi are largely responsible**
- **Drought resistance, salt tolerance, pest and disease resistance are critical traits in Southern agriculture – conventional breeding can sometimes provide crops with these traits but transgenic and synthetic genetics can provide exactly the trait needed in a specific situation**
- **Farmland biodiversity in these areas is often impoverished because the soil is bare due to crop failure and drought**

Crops and biodiversity

- Growing crops can affect biodiversity by:
  - *Indirect* impacts from crop management systems – new and old varieties, cultivation timing and systems, agrochemicals, irrigation, etc etc
  - *Direct* impacts from the crops – toxicity, food for wildlife, gene flow, invasion of natural habitats

What do we know about cropping systems and biodiversity?

- Agriculture damages biodiversity but some biodiversity adapts.
- FSE and other research shows big differences between biodiversity impacts of different cropping systems – whether or not they include GM crops.
- Modern intensive agriculture is driving farmland biodiversity ever lower
- Organic farms have higher biodiversity overall

FSE Results – only HT crops

- Over whole growing season, far fewer weeds (plant density and biomass) and non-crop seed return (up to 80% less) in GMHT rape and beet, but more weeds very early in season.
- Reduction greatest in broadleaved weeds
- Conventional (atrazine-treated) maize had very low biodiversity. Higher weed populations in GMHT maize
- Fewer bees and butterflies in GMHT beet and rape than in conventional crops
- More springtails in GMHT crops in late summer
- Not much impact on field margins, but small increase in herbicide damage to boundaries around GMHT crops

GM crops and their management systems

- **Crop management systems, rather than crops themselves, have the biggest impact on farmland biodiversity (FSE results)**
- **Some GM crops are sold with herbicide management systems that the FSEs showed could either damage or benefit biodiversity, but others such as those with pest and disease resistant traits have been shown to have benefits or have negligible impacts on biodiversity**
- **Research into how GM and conventionally bred crops could be managed to benefit biodiversity is underfunded and therefore almost never done – this is one of the biggest failings of ag. research over past 50 years**
- **We should always compare GM cropping systems with conventional and organic systems BEFORE they are introduced. The same should be done for ANY new cropping system.**

Components of crop sustainability assessment

- Stage one – safety assessment that includes risks to health, potential gene flow. This is a critical step that must be passed before:
- Stage two – assess sustainability of cropping systems compared to current systems
  - Environmental impacts
    - Inputs – quantities and impacts
    - Soil health
    - Water resources
    - Biodiversity
  - Could also include assessment of socio-economic impacts and ethics that affect acceptability and markets
- Stage three – decision based on informed judgement

Conclusions – crop management

- Changes in all crop management systems can affect farmland biodiversity – positive, neutral or negative impacts
- Management of some GM crops can reduce biodiversity, many can give benefits – just like conventional crops, the outcome for biodiversity depends on the crop, the traits, and the way the crop is managed
- Some GMHT crops could be managed to benefit biodiversity – but how can we ensure they are used this way?
- There is great potential in transgenics for reductions in pesticides, irrigation, and perhaps fertiliser – all could benefit biodiversity
- We need methods for assessing the impacts of all novel cropping systems before they are introduced

HOW MUCH GENE FLOW MIGHT OCCUR BETWEEN CROPS AND BETWEEN CROPS AND WILD PLANTS?

Hot research topic for past 15 years – but is it the right question?

Gene Flow and Biodiversity

- **Gene flow will happen between crops and near relatives – Ellstrand**
- **Rates vary according to several factors – somewhat unpredictable**
- **Very little research on the *impacts* of gene flow on *fitness* in semi-natural and agricultural habitats**
- **Some transgenes (e.g. HT) probably have no impact at all in the wild**
- **Many ‘conventionally’ mutated genes give similar traits to GM – e.g. drought tolerance and fungal resistance so there may be similar ecological risks if they spread to wild plants**
- **Some genes may give fitness increases in some habitats – e.g. drought and salt tolerance in arid and estuarine habitats – but we can only guess because the research to estimate fitness has not been done**

Darmency and Gasquez 1990: **Appearance and spread of triazine resistance in common lambsquarters.**

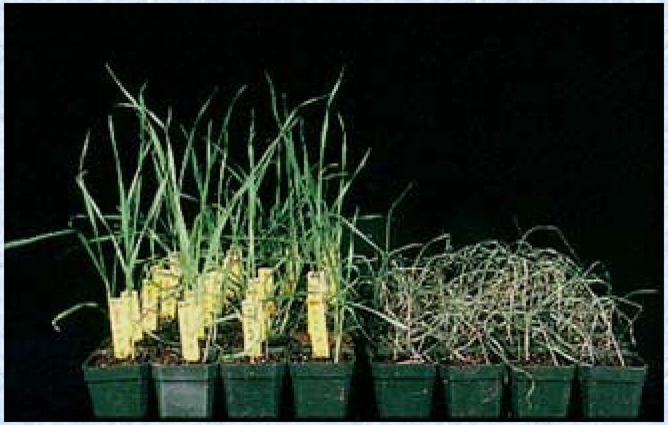
- A single triazine resistant seedling was planted in a number of plots within a maize field.
- Maize field was sprayed with atrazine for 4 consecutive years
- After 4 years, average 103,000 resistant seedlings per plot
- Illustrates invasive potential of plants with new advantageous trait

Snow and Jorgensen 1999: **Fitness costs associated with transgenic glufosinate tolerance…**

- Under lab conditions HT hybrids were developed between oilseed rape and weedy *Brassica rapa*
- Hybrids were found to have incurred negligible fitness **costs**
- Indicates trait may be capable of introgressing into weed population (even in absence of selection pressure from herbicide), and it persists.

Some possible fitness-enhancing traits

Drought tolerant wheat developed by Alessandro Pellegrineschi et al ,CIMMYT



Comparison of DREB and control wheat plants
(DREB plants on the left, control plants on the right in both of the photographs), after 10 days without water.

Drought resistant rice with trehalose genes from bacteria

Developed by Ajay Garg & Ray Wu, Cornell Univ, New York

Salt tolerant rice varieties at IRRI
These are not GM – but there are some GM varieties now available

Weedy rice invades fields in the USA
It cannot be controlled by herbicides

A Malaysian farmer manually removes weedy rice panicles by hand. In Malaysia, weedy rice or *padi angin* was detected in 1988. It is estimated to be causing crop losses of about US$25 million a year in Peninsular Malaysia. (Photo by D. Johnson)

What might happen if drought tolerant and salt tolerant genes (GM or not) were to introgress into weedy relatives of cereals such as wheat, barley and rice?

These might be genes that have never before crossed taxonomic boundaries into these species – so we have no previous natural history

This question can only be properly addressed if the hybrids are made and fitness components estimated in vulnerable habitats like arid and saline ecosystems

Typical desert vegetation on arid and saline soils

Estuary invaded by *Spartina*, a salt tolerant grass

Could salt and drought tolerance genes affect ecosystems?

Saline and arid soils have relatively simple ecosystems with much bare soil (estuaries, deserts, littoral zones)

- These habitats have been invaded by non-natives and hybrids – cases of *Spartina* and in European estuaries, Opuntia in Australia, Tamarisk and grasses in USA
- Very unlikely that novel annual *crops* could be invasive because they are ‘ecologically inept’
- May be long term issues with salt and drought tolerance in perennials such as trees and ornamentals

Challenges for assessment of risks from gene flow

- The main challenge is to estimate and predict fitness changes in habitats that the crop/wild hybrids might colonise – is this really possible?

- It may just be possible for single genes in single hybrids between crops and wild plants – but for stacked complexes?

- How might we do these assessments for entirely synthetic plants? We may be faced with such questions within 20 years, and not just for agriculture.

Conclusions - gene flow

- Genes can and do move freely between sexually compatible taxa
- The rate of transfer is not the main evolutionary factor – it’s recipient fitness
- Risks from transgenes may be no different to ‘conventional’ mutations giving similar traits
- Assessing fitness will be one of the biggest challenges in future risk assessment – but where is the funding and the will to address this?

Thank you for listening

THE ORGANIC RESEARCH CENTRE ELM FARM

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PRACTICAL ACTION